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FINAL THESIS

TITLE: Aging time reduction to increase the production line capacity of LCD television

DEGREE: Diploma in Telecommunication Systems

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Overview

The aim of this project is to make a study on the reduction of the *aging time* of a Sony LCD television to increase its production at the company. The aging time is a period of time when the turned on LCD television is working with a *white pattern*, with the *maximum luminance* and the *maximum backlight* to adjust its colorimetry and luminance levels.

Due to the structure and design of production lines and the capacity needs of the company, the ageing time information specified by Design Department represents a bottleneck at the assembly process of the television. In fact, there are two possibilities to get to the desired result with the necessary time. The first one is to invest in structure and space to lengthen the production lines, and the second and chosen one is to reduce the ageing time to increase the production.

To reduce the ageing time we should find how to model the television behavior out from a mathematical equation. Also, with the help of 6σ parameter we would estimate the behavior and the characteristics of the television with two variables: the television operation time and the television exterior surface temperature, both of them correlated.

With this information we will be able to determine which the minimum aging time is in order to increase the production of televisions.

Títol: Reducció de temps d'Aging per augmentar la capacitat de producció en línies de muntatge de televisió LCD

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Resum

L'objectiu d'aquest projecte és fer un estudi sobre la reducció del temps d'aging d'un televisor LCD Sony per augmentar la producció a l'empresa. El temps d'aging és un període de temps pel qual el televisor LCD està encès i treballa amb una carta blanca, amb la màxima lluminància i màxima backlight per ajustar la colorimetria i els nivells de lluentor.

Degut a l'estructura i al disseny de les línies de producció i als requeriments de capacitat de l'empresa, l'informació del temps d'aging especificat pel departament de Disseny representa un coll d'ampolla pel procés de muntatge de la televisió. De fet, hi ha dues possibilitats per arribar al resultat esperat. El primer d'ells es basa en invertir en estructura i espai per allargar les línies de producció, i el segon i el que utilitzarem es basa en fer una reducció d'aquest *temps d'aging* per augmentar la producció.

Per reduir el temps d'aging hem de trobar com modelar el comportament de la televisió amb una equació matemàtica. A més, amb l'ajuda del paràmetre 6σ , estimarem el comportament i les característiques de la televisió amb dues variables: el temps d'operació de la televisió i la temperatura exterior de la seva superfície, ambdues correlades.

Amb aquesta informació serem capaços de determinar quin és el temps d'aging mínim per augmentar la producció de televisions.

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INTRODUCTION

We are in 2008. Beginning of the 21st Century at an International company as Sony. Can you guess which the most wanted target of a company in the business world is? The answer is obvious: earning money. And increasing the production is one of the ways to do it.

The aim of this project is to present the study of the reduction of Aging time in LCD televisions to increase their production in Sony BCN TEC. In the specifications made by Design Department, the necessary aging time for our model is 30 minutes. Our target is to reduce it to half this time. We will do it out of a mathematical equation with two parameters: the television operation time and the television exterior surface temperature.

We have been supporting Panel Engineering Department of Sony BCN Tec in his studies of new panel model introduction. This department also works on First Failure Analysis (FFA), takes care of the logistics of defective panels (returns the defective panels to the supplier or to the Repair Centre depending on the failure) and gives a daily support to the production line.

In the study, we have taken measures of several panels according to the information and regulation of Design Department, have used Excel program and work with *macros* to operate with the information of the panels, have developed several graphs to contrast the information between them and have used tools like 6σ to make sure we are working with a minimum of quality and reality in our measures.

We have divided the paper into 5 parts according to the chronological order in what we are following the process of aging time reduction.

The first part is an introduction of theoretical concepts. Its aim is for the reader to have the necessary background to follow the process. The main concepts are *White Balance*, *Gamma*, some aspects of *colorimetry* and the concept of 6σ .

The second part of the project is called *Data acquisition*. In it, we explain how to get the characteristic data from the Overall documents that Design Department has written and how to take the measures of Gamma and White Balance adjustments.

In the third part called *Data processing* we talk about the process to take the measures, how to get the mathematical equation to model the wanted behaviour and a comparison between the regular results and the improved results of aging time.

The fourth chapter is called *Data analysis* and summarizes the results. We explain which the final aging reduction is. It has been made through a graph of temperature depending on time for each of the panels.

In the fifth chapter we talk about the *takt time*. In this part, we show a practical case to see why the aging time reduction is so important. It shows how the production line works, how many time lasts each position, which the maximum time for each position is permitted and the comparison between the process with and without the reduction of aging time.

In the last part we expose the conclusions of the project and the advantages of reducing this time.

In the annex we will see some more graphs of the study in order to reaffirm the results obtained.

We have to say that for each new panel model introduction a study of the aging time reduction is done, and this is the study of a determined model, the Sony Bravia KDL-46X3500 (FIX2H LCD 46 inches television).

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CHAPTER 1. THEORETICAL CONCEPTS

In this theoretical explanation we will point out the main concepts of the process of ageing reduction as *White Balance* and *Gamma correction*, some basic aspects of *colorimetry* and the concept of 6σ .

1.1 White Balance

Imbalance of color range in LCD televisions is due to several types of dispersion of the lamps, the panel itself or the amplifiers that are used. To solve this problem, we use a process called *White Balance* which adjusts relative amounts of red, green and blue to correct abnormal tendencies of white color as bluish or oranges shades. After applying this offset at the input, we will obtain the *pure white* at the output and the neutral colors will be reproduced correctly.

This balance can be different adjusted for each company and for each country depending on their likes and needs.

1.2 Gamma

The luminance emitted by some light sources, like lamps of incandescence or cathode ray tubes, is proportional to the applied signal, but this relation is not linear.

In the case of monitors CRT and TFT, the relation between luminance L provided by the screen and the tension V of the signal expressed in volts, is an exponential function,

$$L = V^\gamma \quad (1.1)$$

Where the γ exponent is called *gamma*. A typical value of it is 2.2.

We can also express gamma curve with the register of the pixel level instead of the signal in volts. For example, in *figure 1* we can see a gamma representation with a register of 8 bits and with 255 levels.

$$\text{Number of pixel level} = (2^{8\text{bits}}) - 1 = 255 \text{ levels} \quad (1.2)$$

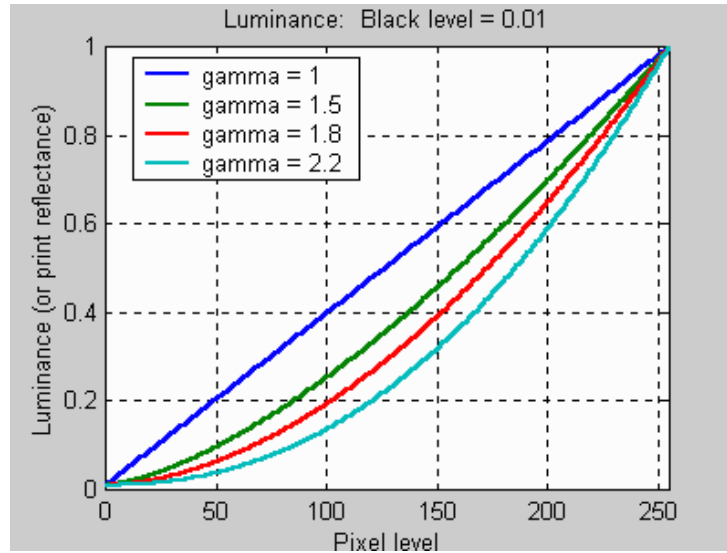


Figure 1.1. Gamma curve

The bigger the gamma factor is, the sharper the curve is and the darker the image is.

The correction could be done with complementary software process in visualization programs. These processes carry out the compensation with LUT (lookup table) conversion tables.

Luminance L of each of the components R, G, and B, turns out in a V signal tension, with the shape of an exponential function (which is inverse to gamma factor). Here we have expression:

$$V = L^{LUT\gamma} \quad (1.3)$$

And also the graph:

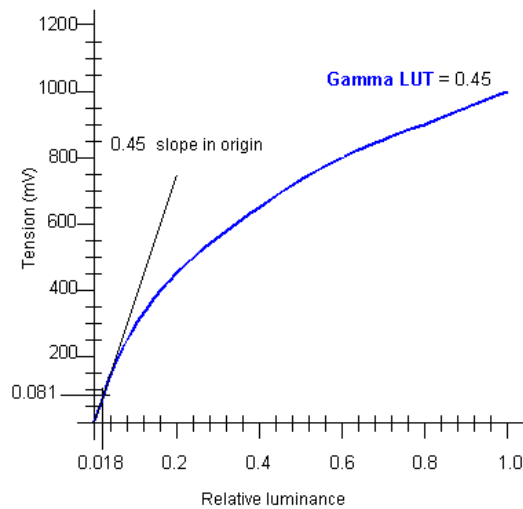


Figure 1.2. Inverse of Gamma factor

1.3 Some aspects of colorimetry

On the one hand, there is a main concept: *the color temperature*. This is the temperature of a source light, which is determined by comparing its chromaticity with a theoretical heated black body radiator. It is expressed in Kelvin degrees.

A candle light has a color temperature of 1700 K and a reddish color (cold), and a xenon lamp has a temperature of 6000 K and a bluish color (hot).

The temperature at which the heated black body radiator matches the color of the light source is that source's color temperature. On the other hand, the path that the color of a black body would take in a particular color space as the black body temperature changes is called *Planckian locus*.

In addition, the human eye has receptors (the cone cells) for short, middle and long wavelengths that describe a color sensation. Furthermore, the *tristimulus values* (*X* for red, *Y* for green and *Z* for blue) are the amounts of the RGB primary colors that describe a specific color.

$$[C_1 = X_1 + Y_1 + Z_1] \quad (1.4)$$

Since the human eye has three types of color sensors that respond to different wavelengths, the plot of all visible colors is a 3-dimensional figure called *color space*. However, the color concept can be divided in 2 parts: *luminance* (which describes the amount of light that passes through or is emitted from a particular area) and *chromaticity* (which measures the purity and hue of a color).

One of the first color spaces that was created by the Commission International de l'Eclairage (CIE) was the *1931 CIE RGB* color space, which specified the quantity of primary color that should be emitted to generate the color. In the late 1920's there was an experiment made by Guild and Wright called *color matching experiment* based on the regulation of the 3 primary lights' brightness to make visually coincide the color of test light. After experimenting with several wavelengths, the outcomes were the *color matching functions*, which represented the RGB contributions of each wavelength. The main problem was that these functions were negative (see *figure 1.3*) and there were no direct information about the brightness unlike the CIE XYZ that we will study immediately next (see *figure 1.4*).

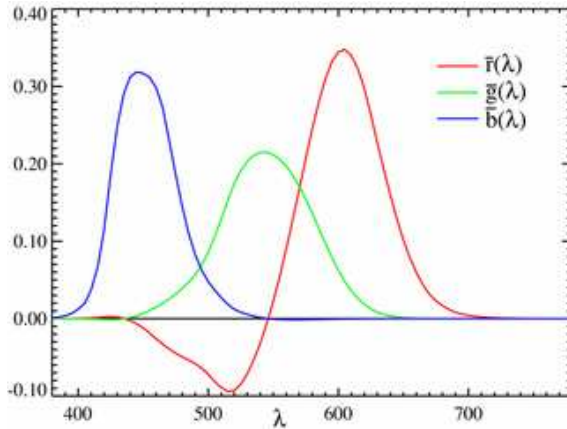


Figure 1.3. CIE RGB color matching functions

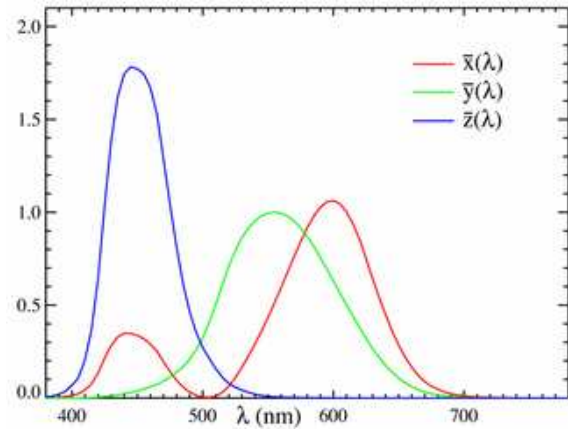


Figure 1.4. CIE XYZ color matching functions

1.3.1 CIE 1931 XYZ color space

After that, the CIE 1931 XYZ color space was created in 1931 and it was one of the first attempts to produce a color space based on measurements of human color perception. It also appeared to avoid disadvantages of CIE RGB: all three functions were positive and there was a direct value for brightness.

This color space was designed so that the Y parameter was a measure of the luminance of a color (measured in nits or candela/m²), and the chromaticity was then specified by the two derived parameters x and y, both of them normalized values which are function of all three tristimulus values X, Y and Z.

$$x = \frac{X}{X+Y+Z} \quad y = \frac{Y}{X+Y+Z} \quad z = \frac{Z}{X+Y+Z} = 1 - x - y \quad (1.5)$$

Figure 1.5 shows the related xyY chromaticity diagram. It is a tool to specify how the human eye will experience light with a given spectrum. It cannot specify colors of objects because the chromaticity observed while looking at an object depends on the light source as well.

Some of the characteristics of the chromaticity diagram should be point out:

- The diagram represents all chromaticity visible to most people. These are shown in color and this region is called the *gamut* of human vision.
- The curved boundary is the *spectral locus*, with wavelengths shown in nanometers, and corresponds to monochromatic light.
- The straight edge on the lower part of the gamut is called the *line of purples*.

- Less saturated colors appear in the interior of the figure with white color at the center.
- Neither devices like scanners, digital cameras nor printers are able to see, capture or reproduce the colors the human eye is. All the colors that are created by mixing three sources are found inside the triangle formed by the source points in the chromaticity diagram (see figure 1.6).
- The corners of the triangle are the primary colors for this gamut, and the vertices of the polygon are the most saturated colors the system can produce.
- This color space is useful if we want to *measure a color*.

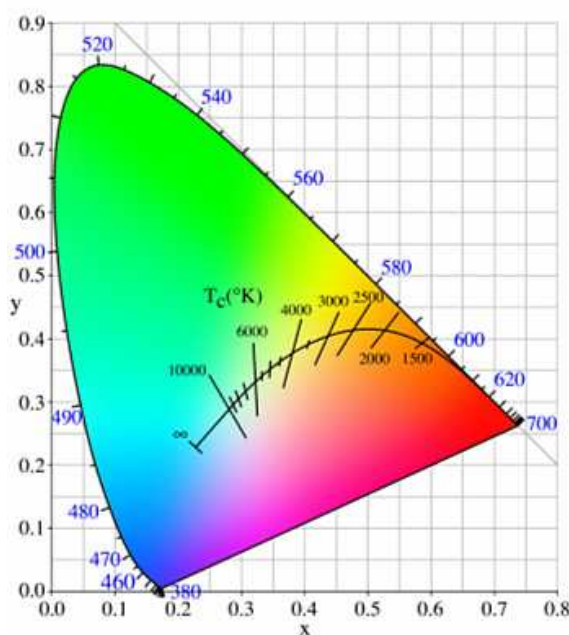


Figure 1.5. *xyY chromaticity diagram and Planckian locus*

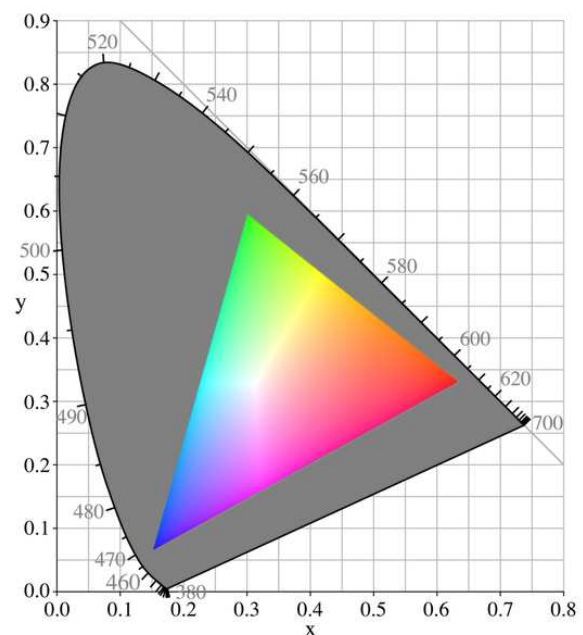


Figure 1.6. *Gamut of a PC*

One of the main topics in the study of color perception was how far apart two colors in the color space were. David MacAdam was the first who dealt with this problem through an experiment. The experiment was based in a trained observer who viewed two different colors. One of the colors (the "test" color) was fixed, but the other was adjustable by the observer, and the observer was asked to adjust that color until it matched the test color. This match was not perfect, since the human eye has limited accuracy. It was found by MacAdam, however, that all of the matches made by the observer fell into an ellipse on the CIE chromaticity diagram.

There are 25 ellipses with different sizes depending on the test color. Since then, they are called *MacAdam ellipse*. (See figures 1.7 and 1.8).

Due to the relative uniform chromaticity of the *1931 color space*, the *just noticeable difference* (JND) of points on the Planckian locus was estimated by Priest to be "a difference of one micro-reciprocal-degree under the most favorable conditions of observation". It is used to distinguish the smallest difference in a specified input that is detectable by a human being.

Since then, there has been many color spaces. Next step was to obtain a uniform color space, meaning that the distance between two points in the space was approximately proportionally to the perceptual distance between the two corresponding colors (as expressed by human viewers).

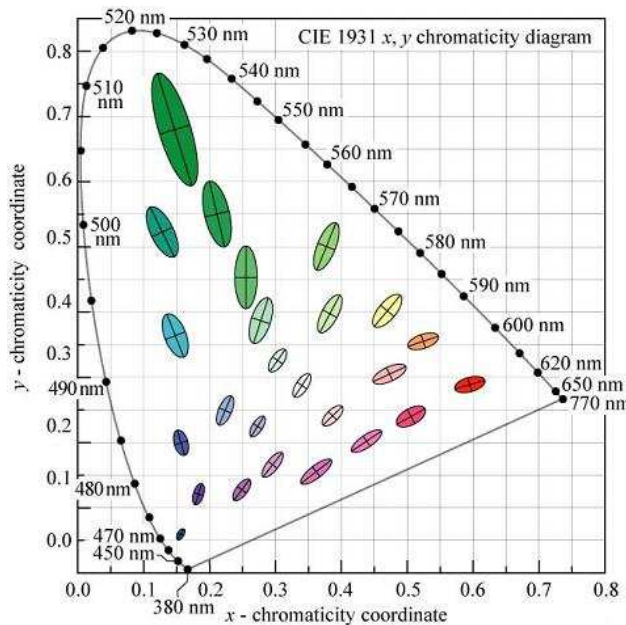


Figure 1.7. MacAdam ellipses in CIE 1931 XYZ

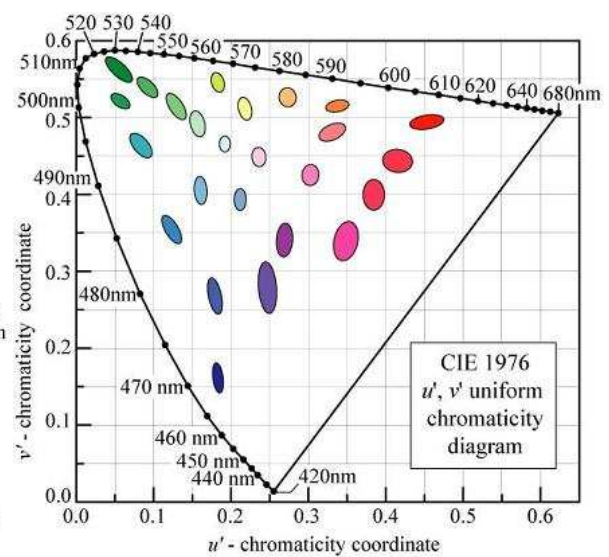


Figure 1.8. MacAdam ellipses in CIE 1976 LUV

1.3.2 CIELUV color space

One of the most remarkable uniform color spaces is *CIELUV*. As well as in *CIE 1931 xyY* chromaticity diagram, it separates the three dimensions of color into one luminance dimension (L) and a pair of chromaticity dimensions (u , v). Although is not completely free of distortion, it is accepted and the MacAdam ellipses become almost circular. This type of color space tries to make possible equal Euclidean distances to be perceived also as perceptual distant. (See figure 1.8).

There are 2 revisions of CIELUV since 1931, *CIE 1960* (u , v) and *CIE 1976* (u' , v') (see figure 1.9.) and 1.10.). Both versions can express their chromaticity in terms of the tristimulus values.

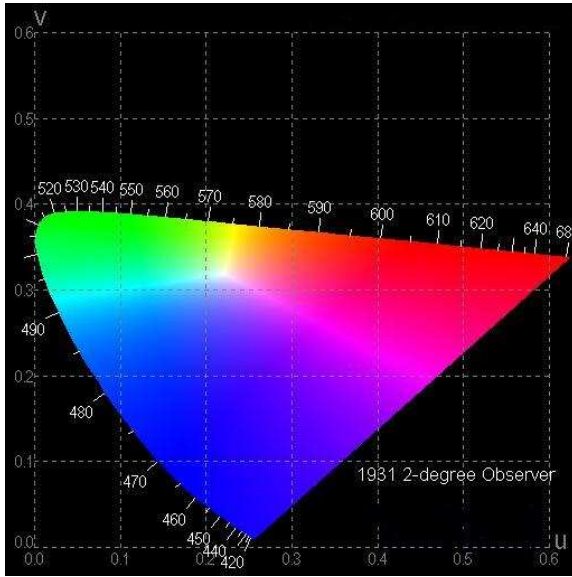


Figure 1.9. CIE 1960 Chromaticity diagram

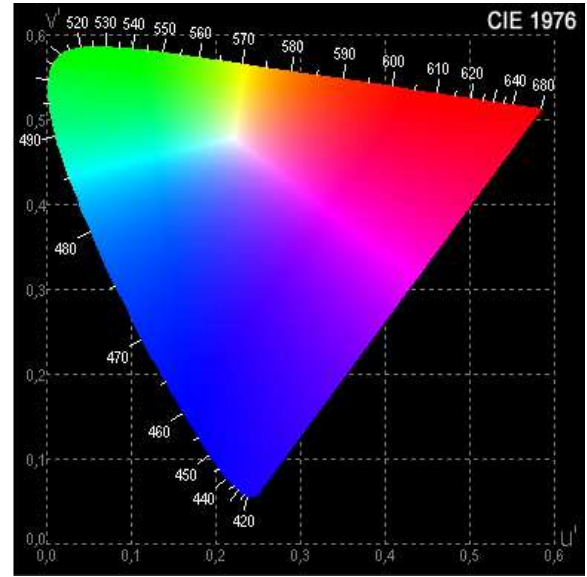


Figure 1.10. CIE 1976 Chromaticity diagram

In the case of *CIE 1960* (u , v) we have:

$$u = \frac{4X}{X+15Y+3Z} = \frac{4x}{-2x+12y+3} \quad (1.6)$$

$$v = \frac{6Y}{X+15Y+3Z} = \frac{6y}{-2x+12y+3}$$

CIE 1976 (u' , v') color space is improved. The distance between points is approximately proportional to the perceived color difference.

The relation between $u-u'$ and $v-v'$ is expressed as follows:

$$u' = u \quad (1.7)$$

$$v' = 1.5v$$

Its chromaticity is expressed like that:

$$u' = \frac{4X}{X+15Y+3Z} = \frac{4x}{-2x+12y+3} \quad (1.8)$$

$$v' = \frac{9Y}{X + 15Y + 3Z} = \frac{9y}{-2x + 12y + 3}$$

And its color difference formula is

$$\Delta E = d \propto \sqrt{(u_a - u_b)^2 + (v_a - v_b)^2} \quad (1.9)$$

a = reference point value

b = known point value

1.4 6 σ (six Sigma)

6 σ is an advanced methodology of the improvement of processes. Its main parameter is the *standard deviation*, and its purpose is to obtain better results through robust processes to reduce variations and defects in what we are doing.

6 σ is commonly used by many as a synonym for *improvement* or *variability reduction*. One of the most important teachings of *Dr. Deming* was to find the variation control of the processes, which is measured with the standard deviation. Dr. Deming said that the enemy of all processes is the *variation*, so that is where we should concentrate the effort of improvement, but above all because “variation is the enemy of our customer’s satisfaction.”

There has been an evolution of improvement since the Sigma concept appeared:

Table 1.1 Sigma values

Sigma	Percentage of reliability
1 σ	68%
2 σ	95%
3 σ	99,73%
6 σ	99,9997%

Depending on what kind of sigma we are using to measure the error in processes, our results will vary from worst condition to better condition.

6 σ is very strict but it assures a 99,9997% of reliability. On the other hand, 1 σ is not so strict but it only assures a 68% of reliability.

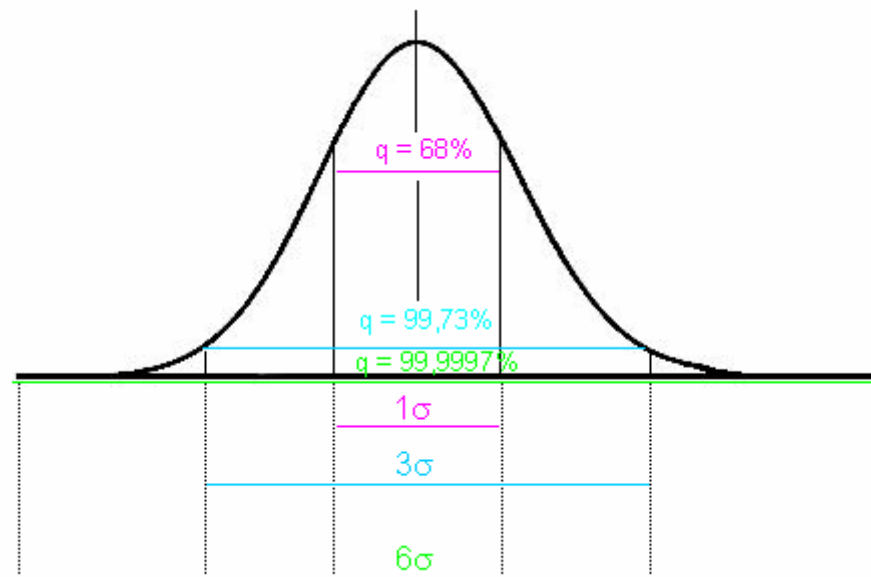


Figure 1.11. Comparison between 1σ , 3σ and 6σ

When the standard deviation of a process is reduced so that its average outcome is six standard deviations from the worst permissible performance, then it is deemed to be a 6- σ process. You are at 6- σ if you achieve the process 99,9997% of the time.

CHAPTER 2. DATA ACQUISITION



In this chapter we will explain how to get the characteristic data about *Gamma* and *White Balance* adjustment of the television Sony Bravia KDL-**46X**3500 (FIX2H LCD 46 inches television) from the overall document.

We will analyze several televisions in our department with the necessary equipment. Since the adjustments and tests do not take place in the production line but in the department, we have to recreate the same conditions. As the worker takes a time to assemble the television and it is warming up from the beginning, we have to simulate this time by having the television turned on. This time is called the *Assembly time* and it takes about 10 minutes.

First of all, we must know which the requested adjustments are made by Design department, all of them gathered in the document *Overall adjustment*. After that, a software program called *Test Stand* is used to get the television data and transferred into a file. Finally, an Excel macro is used to obtain the final graphs and to analyze the results.

2.1 Overall adjustments

The *Overall adjustment* is a document made by Design department which has all the requirements that the television should accomplish. It is divided in three parts: *operation items* or *methods* to follow, *specifications* and *cautions*, and *tools* or *equipments* to use. It is necessary to know what the specifications are to know which the purpose is and to fix possible imbalances.

For a 46 inches television, the ageing time to reduce is 30 minutes and the temperature in surrounding is between 22 °C and 28 °C.

Table 2.1 Aging time for panel sizes

Panel size	Aging time
40 inch	30 min or more
46 inch	30 min or more
52 inch	30 min or more

Ambient temperature = 22 - 28 Celsius degrees

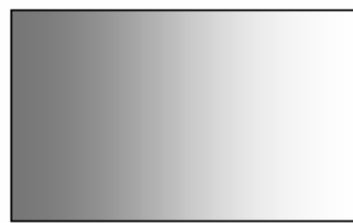
Moreover, in Overall specifications, Gamma and White Balance adjustments are also described.

2.1.1 Gamma adjustment

The JIG adjustment measures luminance at some different levels of brightness. Then it calculates the offset necessary to adjust the new response. Finally, JIG decides how to adjust gamma with the value of these registers.

The main characteristics of gamma adjustment are:

- *Value of gamma* should be adjusted to 2.2 under setting condition.
- *Measurement point* should be in the center of the screen with a color analyzer.
- When measuring each level of brightness (11 points), test pattern should be only a green signal.
- There is a *calculating tool* which gives correction-value for adjusting the value of gamma to 2.2. This correction is calculated from 512 points originated with actual 11 points.
- The inspection of a correct adjustment should be done using a ramp signal.



Displaying ramp image regularly



Displaying irregular line in ramp image.
(Black line in this figure is an example.)

Figure 2.1. Figures for the inspecting adjustment: Left-side being adjusted correctly; Right-side being adjusted incorrectly

2.1.2 White Balance adjustment

The main characteristics of White Balance adjustment are:

- The *adjustment equipment* would be a Color Analyzer.

- The adjustment is based on several brightness tests (20 IRE, 30 IRE, 50IRE, 70IRE and 90IRE) at different color temperatures: cool, neutral, warm1 and warm2.

Table 2.2 Overall adjustments

		W-Model				X-Model			
	Color temp.	Cool	Neutral	Warm 1	Warm 2	Cool	Neutral	Warm 1	Warm 2
	MWBTD_	3	2	1	0	3	2	1	0
40"	x	0.2704	0.2815	0.2931	0.3134	0.2704	0.2815	0.2931	0.3134
	y	0.2707	0.2848	0.2979	0.3251	0.2707	0.2848	0.2979	0.3251
	u'	0.1895	0.1923	0.1958	0.1998	0.1895	0.1923	0.1958	0.1998
	v'	0.4269	0.4378	0.4477	0.4663	0.4269	0.4378	0.4477	0.4663
	T+MPCD *	12000K-6	9300K+0	8000K+0	6500K+8	12000K-6	9300K+0	8000K+0	6500K+8
	T+duv *	12200K-0.0024	9300K+0	8000K-0.0001	6500K+0.0032	12200K-0.0024	9300K+0	8000K-0.0001	6500K+0.0032
46"	x	0.2704	0.2815	0.2931	0.3134	0.2704	0.2815	0.2931	0.3134
	y	0.2707	0.2848	0.2979	0.3251	0.2707	0.2848	0.2979	0.3251
	u'	0.1895	0.1923	0.1958	0.1998	0.1895	0.1923	0.1958	0.1998
	v'	0.4269	0.4378	0.4477	0.4663	0.4269	0.4378	0.4477	0.4663
	T+MPCD *	12000K-6	9300K+0	8000K+0	6500K+8	12000K-6	9300K+0	8000K+0	6500K+8
	T+duv *	12200K-0.0024	9300K+0	8000K-0.0001	6500K+0.0032	12200K-0.0024	9300K+0	8000K-0.0001	6500K+0.0032

Table 2.3 JND specifications for each signal level

Signal level	Spec(JND)	Spec($\Delta u'v'$)
90IRE	0.3	0.001
70IRE	0.3	0.001
50IRE	0.5	0.002
30IRE	0.8	0.0025
20IRE	1.0	0.003

The chromaticity coordinates are well-adjusted if they are in specifications. For example, at 20IRE, u' , v' coordinates have to be below 1 JND related to the overall target.

In addition to the *Overall adjustment*, Design Department also follows the *Quality Control Standard*, a requirement of Quality Control.

Table 2.4 Quality Control adjustments

Signal level	Spec(JND)	Spec($\Delta u'v'$)
90IRE	2.0	0.006
70IRE	2.0	0.006
50IRE	2.0	0.006
30IRE	2.0	0.006
20IRE	2.0	0.006

As we can see in *figure 12*, the u' and v' coordinates at any signal level have to be below 2 JND related to the overall target. This is to say that the total amount of *Aging Reduction error* and *Overall adjustment* can not exceed 2 JND.

We can see it with an example:

70 IRE

$$\underbrace{0,3 \text{ JND overall adjustment}}_{\text{fixed value}} + \text{up to } 1,7 \text{ JND aging reduction error} = 2 \text{ JND}$$

50 IRE

$$\underbrace{0,5 \text{ JND overall adjustment}}_{\text{fixed value}} + \text{up to } 1,5 \text{ JND aging reduction error} = 2 \text{ JND}$$

20 IRE:

$$\underbrace{1 \text{ JND overall adjustment}}_{\text{fixed value}} + \text{up to } 1 \text{ JND aging reduction error} = 2 \text{ JND}$$

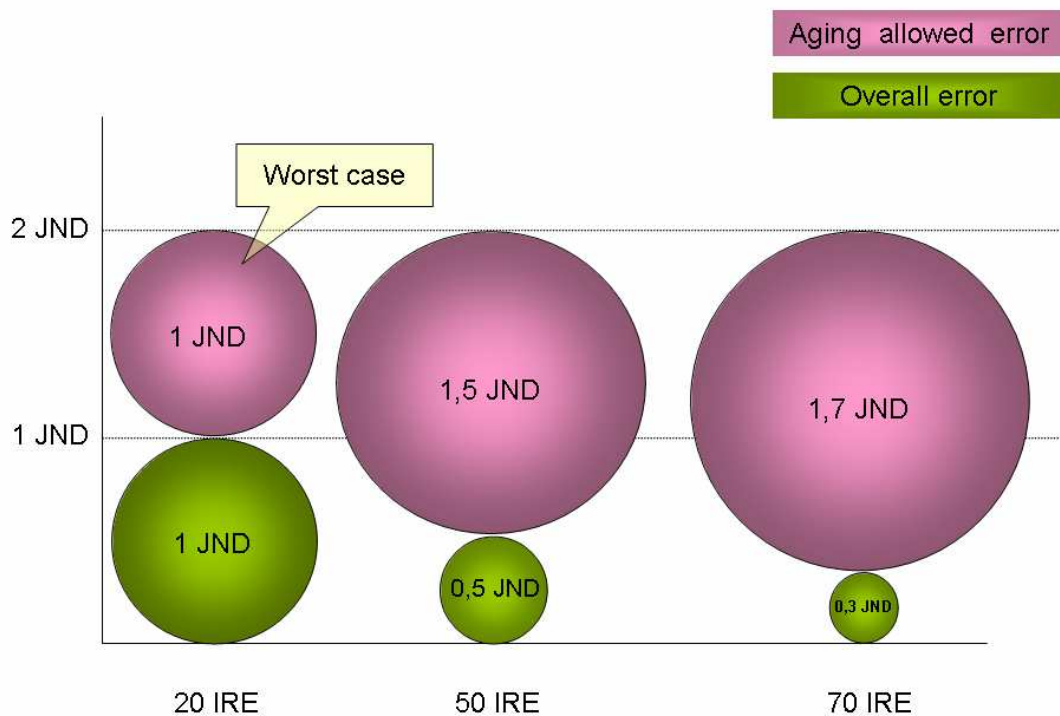


Figure 2.2. Allowed errors of aging and overall adjustments

As we can see in *figure 2.2*, the level of brightness that has less margin of operation is 20 IRE. This is due to the fact that the Overall adjustment is fixed by the document of the same name, and its aging reduction error is the smallest.

We are working at worst conditions. Consequently, we will set 1 JND of *aging reduction error* for all signal levels. That way we are shrinking the operation margin and our position is the most pessimistic.

2.2 Logs

When analyzing a television of a determined model, testing just one is not enough. For that reason, 4 or 5 sets are analyzed at 2 different temperatures: 18 °C and 25 °C.

When using the program *Test Stand* we obtain some data as the *hour* of the analysis, the chromaticity coordinates u' and v' , the *luminance* and the *temperature* for each one of the 11 points of green signal (from 0_gamma to 10_gamma). We check the previous data for different types of color temperature: *cool*, *neutral*, *warm1* and *warm2*, and for five types of brightness: 20, 30, 50, 70 and 90 IRES.

CHAPTER 3. DATA PROCESSING

In this section we are going to obtain and analyze the data. We will explain the procedure that we carried out to get the data, its meaning, and some comparisons between the most significant.

We can get all the information from the macros that we use to create the graphs: the Gamma macro and the White Balance macro.

In this case, we have analyzed 4 sets at 25 °C and 2 sets at 18 °C. This is why the name of the sets has the structure of *reference number_starting temperature* → 4600080_25.

3.1 Gamma graphs

In this case we have measures of luminance and temperature for each one of the 11 registers of green pattern.

The procedure to analyze Gamma data is the following one:

1. We need to measure 11 points of gamma using the *p_vmx_tpg_gy [HREG]* register from 0 to 1023 for adjustment (0, 64, 128, 192, 256, 384, 512, 640, 768, 896 and 1023), so we will study the evolution of luminance depending on the temperature for each point.
2. The response is a parabola, which behaves like the expression that is above:

$$y = \mathbf{a}x^2 + \mathbf{b}x + c \quad (3.1)$$

We will also represent the tendency lines for each parabola. That way, we will obtain the equation of the parabola for each register.

In *figures 3.1, 3.2 and 3.3* we can see *Luminance vs Temperature* graphs of registers 128, 512 and 1023 where each colored line represents a set and the red line represents the parabola average.

In graph of register 128 (*figure 3.1*), lines are almost plane because the luminance is so low that the differences are difficult to distinguish. As the register increases, luminance increases and parabolas are more curved due to the fact that they have more levels to reach. First, they experiment a high peak, and after that they begin to decrease and establish.

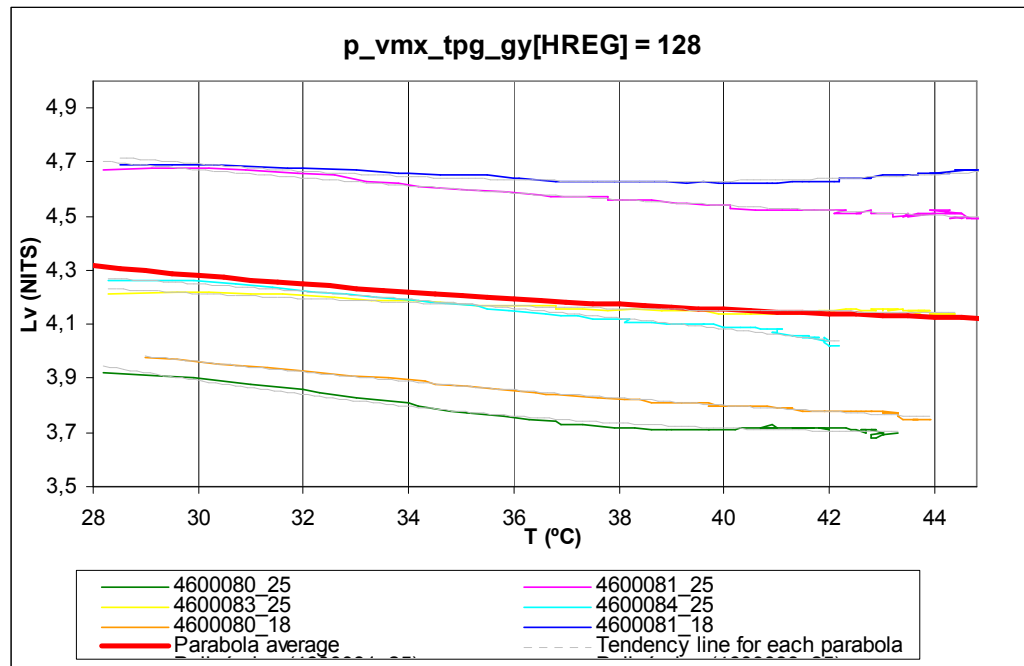


Figure 3.1. Lv vs T (reg = 128)

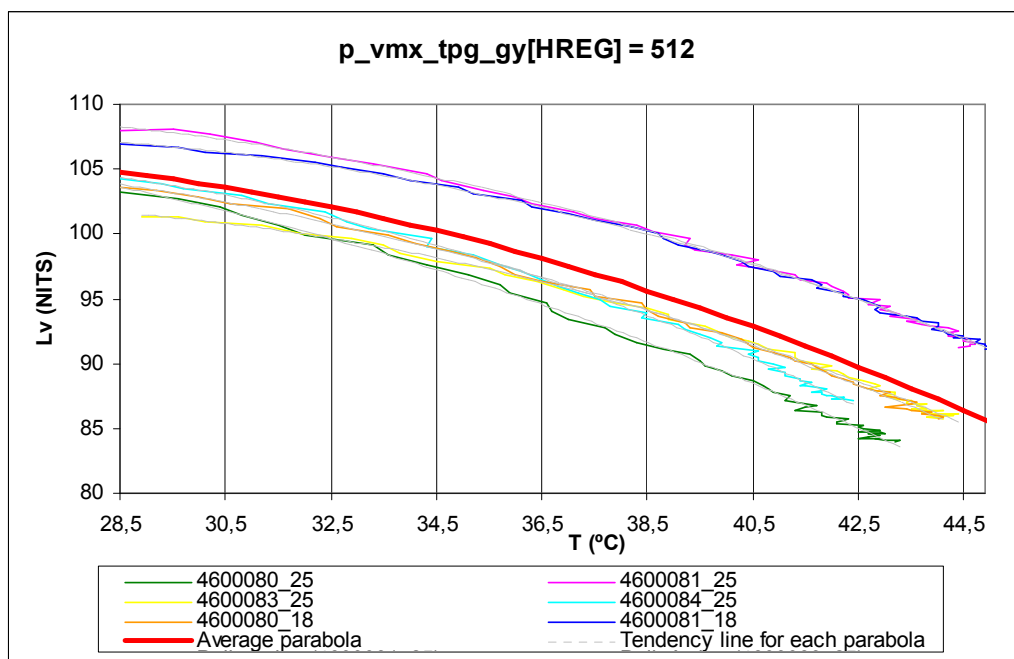


Figure 3.2. Lv vs T (reg = 512)

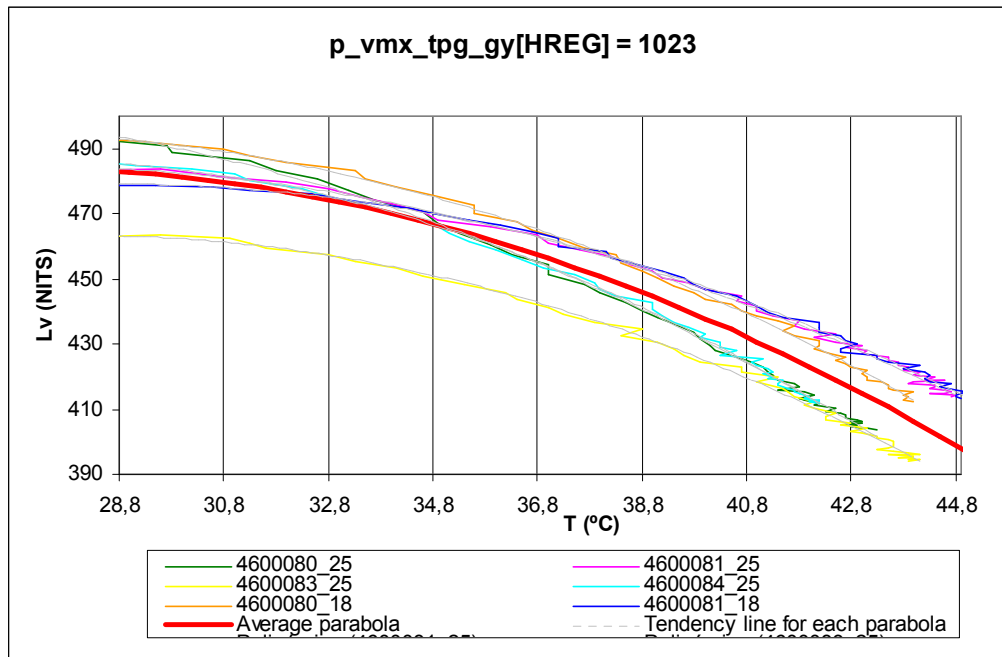


Figure 3.3. Lv vs T (reg = 1023)

Continuing with the process, after obtaining the equations for each parabola, we will average both a and b values just to have one value for level of brightness.

Table 3.1 a and b values for each level of brightness

	a	b
0	-0,000092227583333	0,004110697216667
64	0,000253124100000	-0,023257469283333
128	0,000425257966667	-0,042426444650000
192	-0,001328990916667	0,046367488783333
256	-0,005291134183333	0,248615611666667
384	-0,019780798650000	0,928630159116667
512	-0,039638641800000	1,740040726183330
640	-0,071827028600000	3,214266578183330
768	-0,115731119766667	5,244863615633330
896	-0,187069373733333	9,121712457950000
1023	-0,256252109216667	13,597598521583300

With these values, the JIG adjustment can calculate the luminance prospect and, then, TV set adjust the gamma by internal software.

Once we have these values we are going to determine the response of the luminance achieved at 30 minutes aging that will be called $Lv_{overall}$.

We will use the parabola expression to determine the $Lv_{overall}$ response. In this case, luminance depends on temperature, so temperature will be in x axis and luminance in y axis:

$$y = ax^2 + bx + c$$

$$Lv_{overall} = aT_{average}^2 + bT_{average} + c$$

$$Lv_{now} = aT_{now}^2 + bT_{now} + c$$

(3.2)

$$Lv_{overall} - Lv_{now} = (aT_{average}^2 + bT_{average} + c) - (aT_{now}^2 + bT_{now} + c)$$

$$Lv_{overall} - Lv_{now} = a(T_{average}^2 - T_{now}^2) + b(T_{average} - T_{now})$$

$$Lv_{overall} = Lv_{now} + a(T_{average}^2 - T_{now}^2) + b(T_{average} - T_{now})$$

To get the $T_{average}$, we have to average set temperatures at 30 minutes ageing. In our case we will analyze televisions of registers number 128, 512 and 1023.

Table 3.2 $T_{average}$ for each register

Register	$T_{average}$ (°C)
128	40,8
512	40,82
1023	40,7

In this graph we can see the $T_{average}$ of register 512 at 30 minutes ageing. The temperature is 40,82 °C.

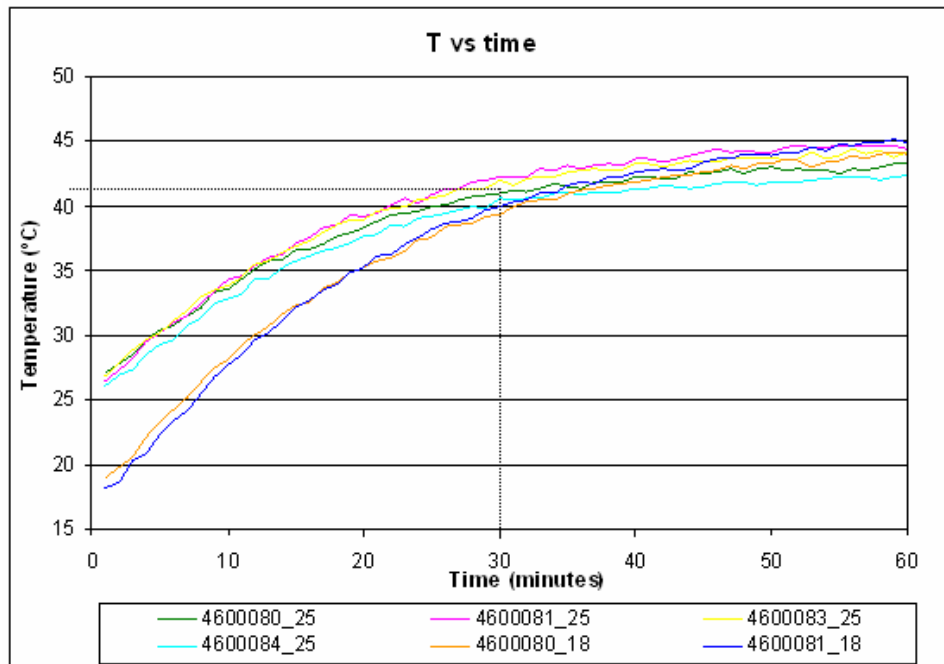


Figure 3.4.. Average temperature, also known as $T_{overall}$

Now that we have $T_{average}$ for the selected registers, we can calculate the $Lv_{overall}$.

First comparison will be between the luminance with offset ($Lv_{overall}$) and the luminance without offset (Lv_{now}).

Our aim is for each response to be as uniform as possible in order to have the same value as the one at 30 minutes ageing (*overall*), which is represented as a black discontinuous line. Differences are represented with a vertical red line. (See *figures 3.5 and 3.6*).

This is an example with register 128 for the set 4600081_25 at approximately 34 °C. (For a and b values we have used 9 decimals but we only have written 5 at the example).

If we check the representations in *figure 3.5.*, we can see the purple line with the value of 4,61 as Lv_{now} , and the discontinuous black line with the value of approximately 4,5.

$$Lv_{overall} = Lv_{now} + a (T_{average}^2 - T_{now}^2) + b (T_{average} - T_{now})$$

$$Lv_{overall_4600081_25} = 4,61 + 0,00042 (40,8^2 - 34,2^2) + (-0,04242 (40,8 - 34,2)) =$$

$$Lv_{overall_4600081_25} = 4,54$$

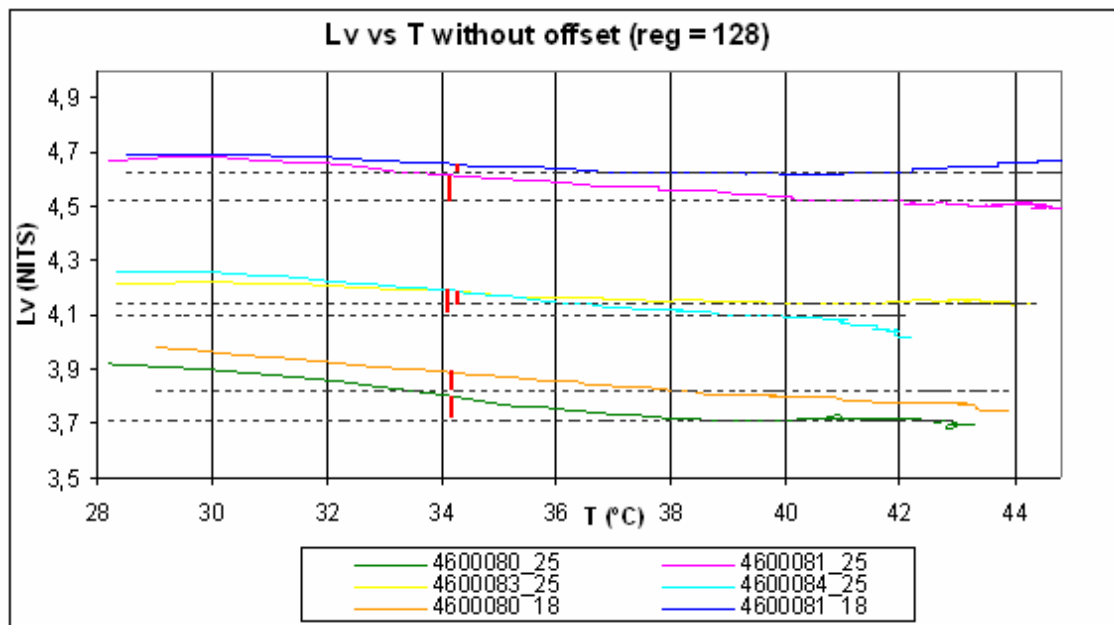


Figure 3.5. Lv vs T w/o offset (reg = 128)

The same representation is done for the *Luminance vs Temperature* (with offset). This is to say, with the ideal values of luminance.

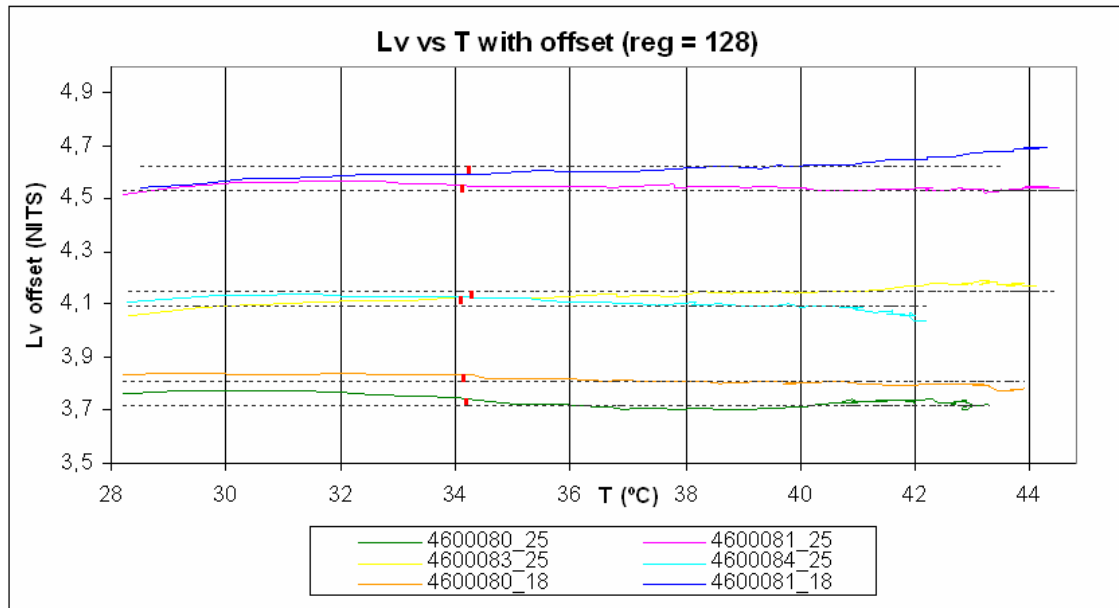


Figure 3.6. Lv vs T with offset (reg = 128)

Comparing *figures 3.5 and 3.6* the error is noticeable by means of the red line.

To better quantify the error, we are going to represent a graph in which the error between optimum value and real parabola is expressed in percentage and the technical 6σ tool is applied.

In this case, we will represent 6σ graphs about *Luminance error with offset* and *without offset* for registers 128, 512 and 1023.

We have to say that the range of measuring temperatures was from 25 °C for 4 sets and from 18 °C for 2 other sets to 45 °C. However, we have represented temperature from 28 °C due to the fact that when the set is beginning to warm up, is not stable and the values are not reliable.

1. We will calculate the relative error to measure the differences of value:

$$\text{rel error} = \left(\frac{\text{Absolute (Lv overall (for each T) – average Lv at 30 min aging)}}{\text{average Lv at 30 min aging}} \right) \times 100 \quad (3.3)$$

We should classify the values of luminance and their respective relative error by temperature, in order to have all the sets ordered.

2. Once we have ordered the values there will be some gaps due to the organization by temperature. We will solve this problem by interpolating the values. Consequently, the representation of the error can not be totally uniform.

3. After that we will calculate some values: *Standard deviation* of the relative error (also known as *sigma*) and the *average of the relative error* (as a matter of reference).

As we were saying before, these graphs represent the luminance error with and without offset in percentage. The relative error is represented in color for each set and the red line represents the average of the errors.

Another important representation is the *error average* + 6σ (the one in green color). The main characteristic of this standard deviation is showing how similar is the behavior of the sets by being far away from each other. So, it represents 6 times the error plus the average of the luminance differences of each set.

Some of the main characteristics of the graphs are the following ones:

- There is a point in both graphs where the error is 0%. This is the point at the temperature of 30 minutes ageing (40,8 °C for this register). All the values of relative error are divided by this temperature so that is why there is no error.
- We also have to remember that at lower temperatures, the set is not perfectly stable so this is why the error is so noticeable at 28 °C in both cases and why 6σ is so high.

And then, for registers 128, 512 and 1023 we will analyze the *error between response with and without offset*, and the *behavior of 6σ* .

Register 128

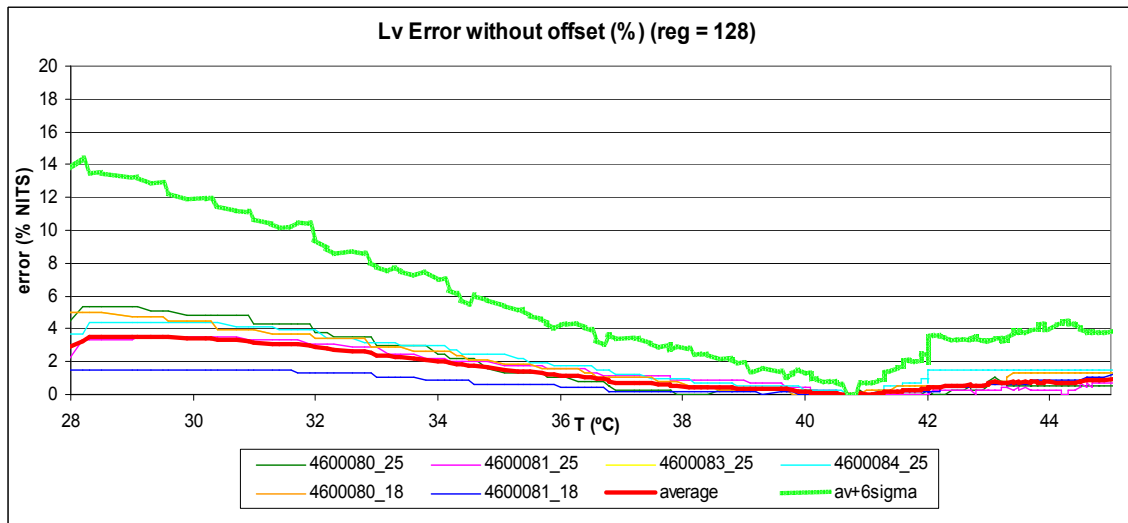


Figure 3.7. Lv error without offset

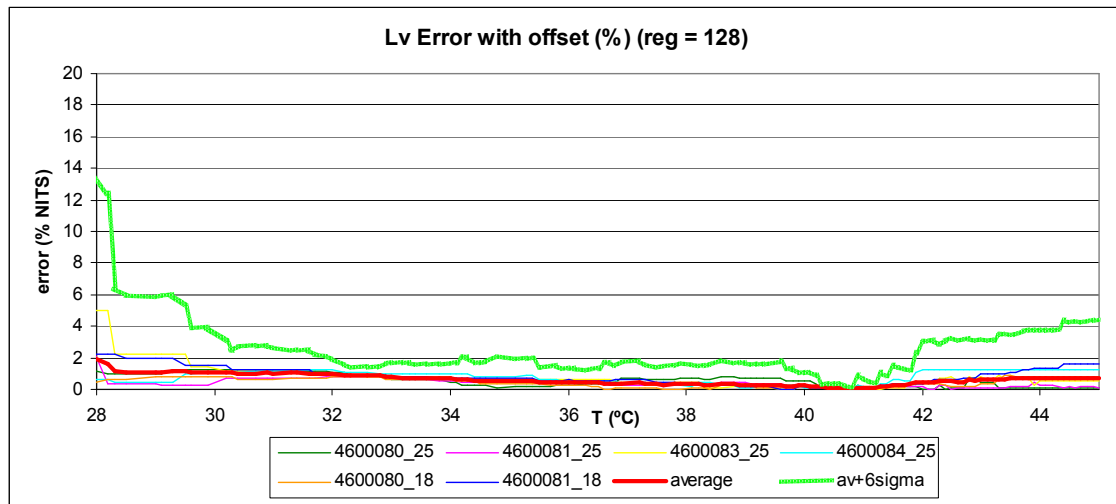


Figure 3.8. Lv error with offset

In register 128,

If we observe the *error between response with offset and without it* we realize that from the lower temperature to 37 °C, the error of luminance of the response without offset is approximately 3 times higher than the response with offset. (We will pay attention on the average line).

3% (without offset) vs. 1% (offset) at 30 °C → **3 times higher**
 1,25% (without offset) vs 0,5% (offset). at 36 °C → **2,5 times higher**

From 37 °C to higher temperatures, the error is similar in both cases. This is due to the fact that average temperature at 30 minutes is close to higher temperatures and there is less dispersion.

0,25% (without offset) vs. 0,25% (offset) at 42 °C → same error

On the other hand, the 6σ behavior in the response with offset is near the average in almost all the temperatures, which means that all the sets have a similar behavior, however, in the response without offset, the response is far from the average at the beginning and become nearer as the temperature approaches 40,8 °C.

Register 512

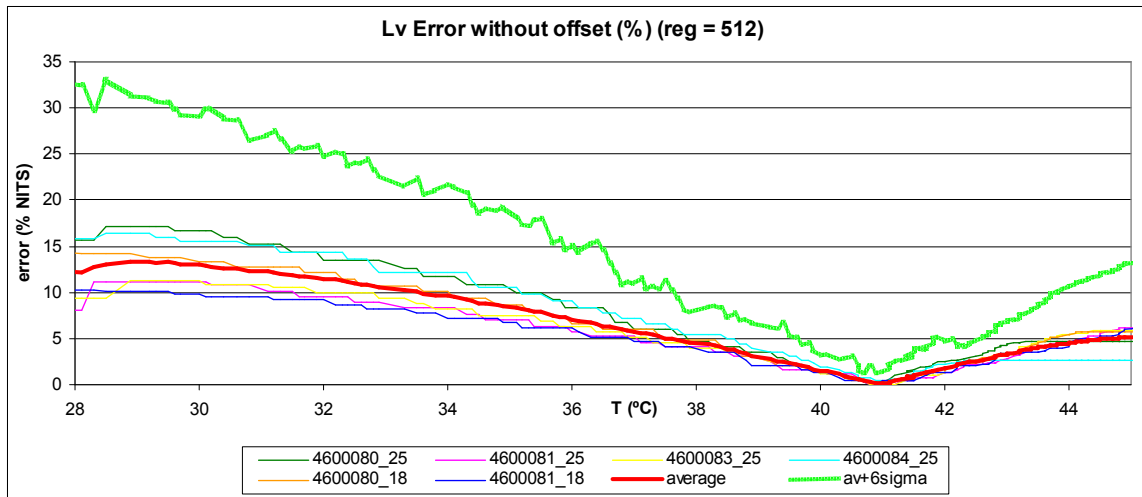


Figure 3.9. Lv error without offset

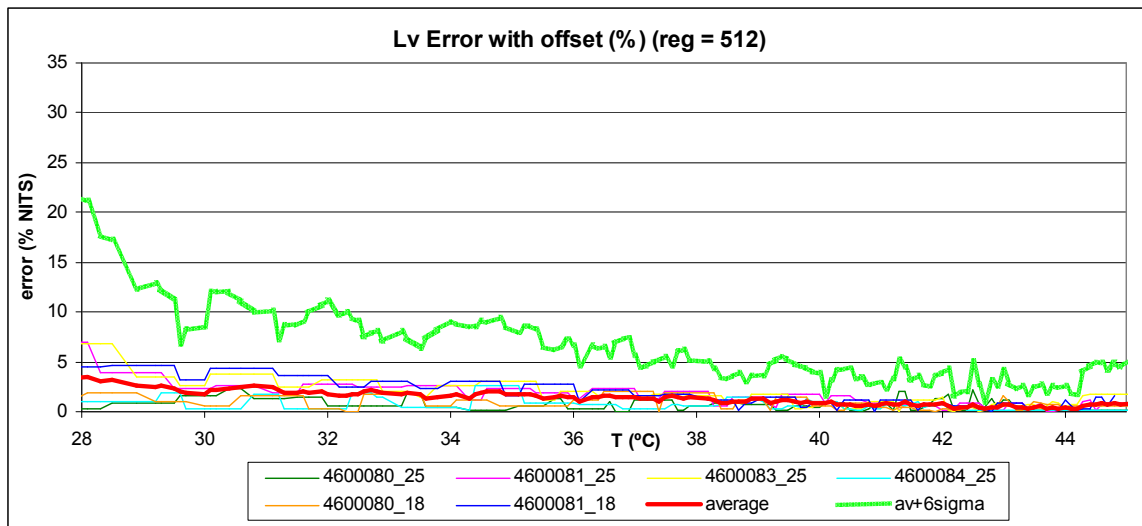


Figure 3.10. Lv error without offset

In register 512,

We can perceive little smoothness in the response of the sets. This is due to the fact that the temperature at what we measure de luminance has big intervals,

and if one set measures at 35 °C and the next measure is at 36 °C, there will be the same 9 values of luminance until the next temperature.

The *error between response with offset and without it* is higher than in the previous register. It is due to the fact that the register 128 has low luminance and the values are small. In register 512 there is more available information and consequently, more errors:

13% (without offset) vs. 2% (offset) at 30 °C → **7 times higher**
 9,6% (without offset) vs. 1,5% (offset) at 34 °C → **6,5 times higher**
 4,5% (without offset) vs. 1,5% (offset) at 38 °C → **3 times higher**
 3,2% (without offset) vs. 0,75% (offset) at 43 °C → **4,4 times higher**

In the case of 6σ , its response is far from the average in both cases at low temperatures, and then begins to become near as the temperature increases up to 40,8 °C (average temperature at 30 minutes ageing of register 512).

Register 1023

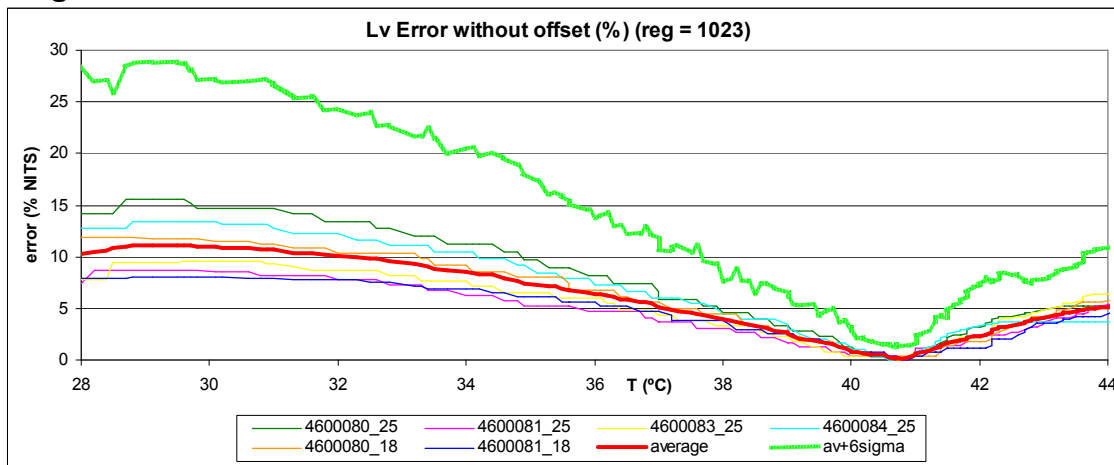


Figure 3.11. Lv error without offset

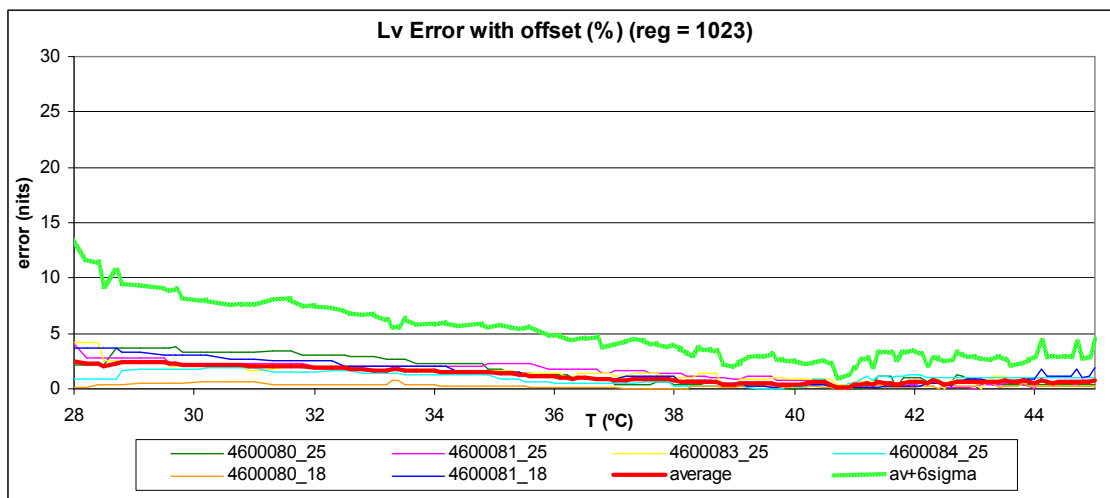


Figure 3.12. Lv error with offset

This last register shows us smoother lines because the intervals are not so big as they used to be in register 512.

The *error between responses with offset and without it* in this case is a bit slighter compared to the error in the previous register. This is because the luminance is higher and there are more levels to reach:

10,3% (without offset) vs. 1,9% (offset) at 30 °C → **5,4** times higher
 6,4% (without offset) vs. 1,1% (offset) at 34 °C → **5,8** times higher
 0,7% (without offset) vs. 0,4% (offset) at 38 °C → **1,75** times higher
 3,2% (without offset) vs. 0,75% (offset) at 42 °C → **3,88** times higher

The 6σ behavior is very similar to the other registers. As the response approaches the average temperature of 30 minutes ageing (in register 1023 is 40,7 °C) it is nearer the error average.

To have a better point of view, there is a little complementary study. It is shown in the annex, in *7.1 Gamma graphs*.

3.2 White Balance graphs

We can create graphs such as du' vs T , dv' vs T , ΔE vs *panel's surface temperature*, and ΔE offset vs *panel's surface temperature*. These 4 graphs help us to understand the behavior depending on the temperature of the television.

3.2.1 du' vs T and dv' vs T

These graphs have two coordinates: differences of u' and v' (du' , dv') and temperature.

First of all, there is a reference point that help us to quantify these differences of chromaticity. This point is the *average temperature of television at 30 minutes ageing*. Once we have this point, we can calculate du' and dv' . Let's exemplify this process of a television with 20 IRES of brightness:

1. All the televisions are turned on during 1 hour.
2. We have the temperature average after 30 minutes ageing.
3. We compare each u' with the u' after 30 minutes ageing and that way we get the differences of u' (du').
4. After that we get the graph of du' depending on temperature for each television, which is a parabola.
5. Finally we get an average parabola of the televisions.

The same procedure is used to calculate dv' .

Average temperature of television at 30 minutes = 40.9 °C

$$u'_{30 \text{ min}} = u' \text{ at 30 minutes ageing (40,9 °C)} = 0,1847$$

$$u'_i = u' \text{ at the temperature } i \text{ (27,9 °C)} = 0,185$$

$$du'_i = u'_i - u'_{30 \text{ min}} = 0,185 - 0,1847 = 0,0003$$

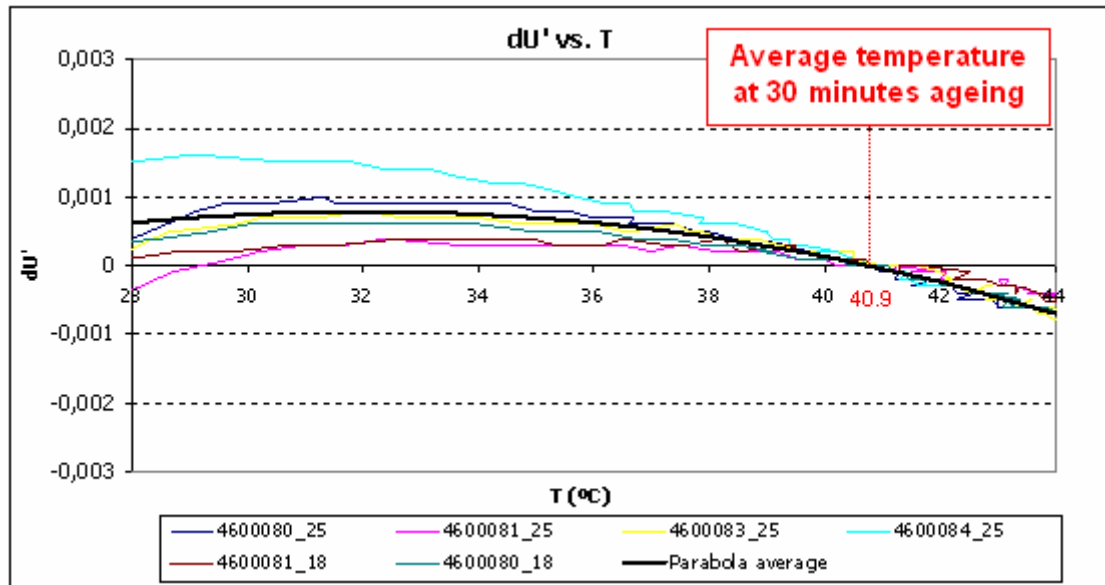


Figure 3.13. Graph du' vs T

The same procedure is used to calculate dv' .

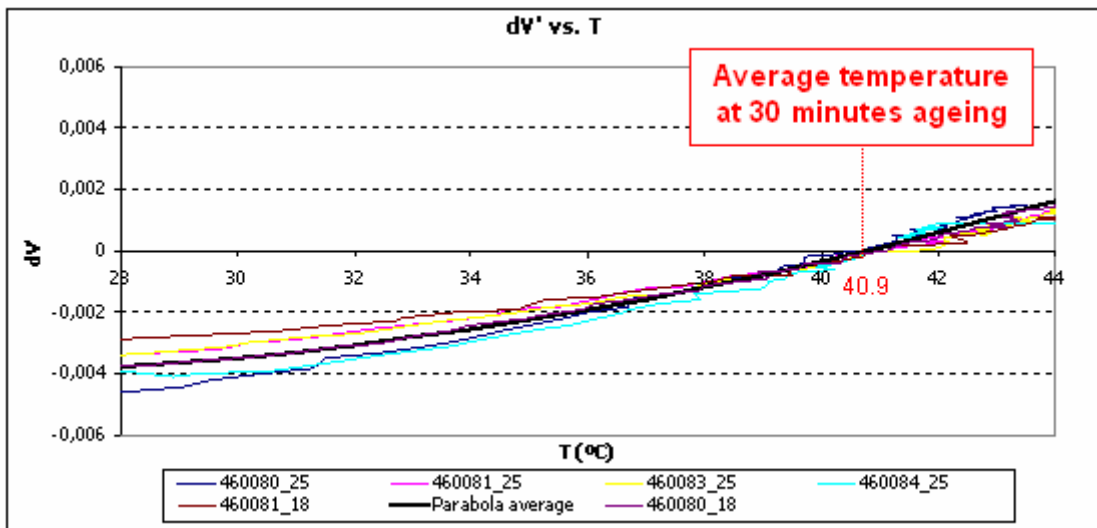


Figure 3.14. Graph dv' vs T

3.2.2 ΔE with and without offset

ΔE graphs show us the distance between the coordinate (u' or v') we ideally want to be and the real coordinate in which we are now.

The procedure to create these graphs is very similar to the Gamma graphs. First of all, we get the average temperature at 30 minutes ageing for each of the sets. We will have u' , v' , L_v and T values, and we will obtain differences of u' and v' (du' , dv').

As a matter of example, we will obtain ΔE for the signal level at 20 IRE cool. We will calculate it for minute 2:

- T_{average} of all sets at 20 IRE cool = 40,82 °C
- Minute of T_{average} of the set 4600080_25 = *minute 29* (40,9 °C)

$$du'_2 = u'_2 - u'_{29} = 0,1850 - 0,1847 = 0,0003$$

$$dv'_2 = v'_2 - v'_{29} = 0,4292 - 0,434 = -0,048$$

$$\Delta E_2 = \sqrt{du'^2_2 + dv'^2_2} = (0,0003)^2 + (-0,048)^2 = 0,00481$$

This is the real ΔE , the one that we obtain without applying any offset. After the u' v' offsets have been applied, the ΔE is corrected for each temperature in order to achieve the 30 minutes ΔE condition. For a and b values we have used 9 decimals but we only have written 5 in the example:

$$\begin{aligned} u'_{\text{overall}_1 \text{ set}} &= u'_{\text{now}} + a (T_{\text{average}}^2 - T_{\text{now}}^2) + b (T_{\text{average}} - T_{\text{now}}) \\ &= 0,1850 + (-0,000011 (40,82^2 - 27,9^2)) + 0,000715 (40,82 - 27,9) = \\ &u'_{\text{overall}_2} = 0,1844 \end{aligned}$$

Following the same procedure we get $v'_{\text{overall}_2} = 0,4331$

$$du'_{2_ \text{overall}} = u'_{2_ \text{overall}} - u'_{29} = 0,1844 - 0,1847 = -0,0003$$

$$dv'_{2_ \text{overall}} = v'_{2_ \text{overall}} - v'_{29} = 0,4331 - 0,434 = -0,0009$$

$$\Delta E_{2\text{overall}} = \sqrt{du'^2_{2_ \text{overall}} + dv'^2_{2_ \text{overall}}} = (-0,0003)^2 + (-0,0009)^2 = 0,00092$$

To have a better point of view, we will do a comparison of the value of (*average* + 6σ) at 28 °C to see which the worst case is.

There is a little complementary study. It is shown in the annex, in 7.2 *White Balance graphs - ΔE with and without offset.*

Table 3.3 Comparison of *average* + 6σ at 28 °C

Name	20_cool	30_cool	50_cool	70_cool	90_cool	20_neut	20_w1	20_w2
dE at 28 °C	0,003	0,0024	0,0028	0,0027	0,0025	0,0029	0,0036	0,0026

The results show that at 28 °C all values of ΔE are in specifications of *ageing reduction error (below 1 JND)* except the one at 20 IRE warm1. In this case we can not set 28 °C as the reference temperature, so we have to increase it until the value of temperature will be below 1 JND.

This temperature is **29 °C**.

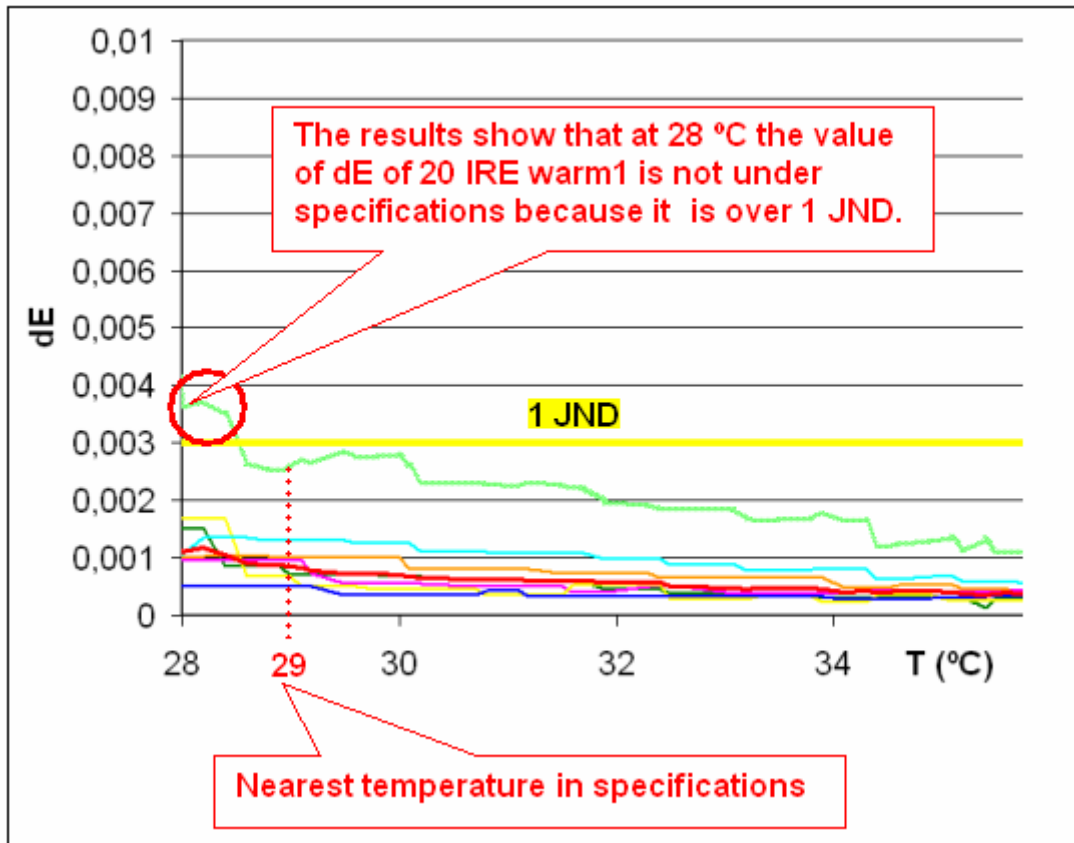


Figure 3.16. Enlargement of graph of 20 IRE warm1

CHAPTER 4. DATA ANALYSIS

Now that we know which the *reference temperature* is and which the *register has the worst behavior*, we will analyze the *temperature vs time graph* to get the aging time reduction.

Reference temperature: 29 °C

Worst condition:

(average between sets 4600081 and 4600080 at 18 °C) – (6σ) → green line

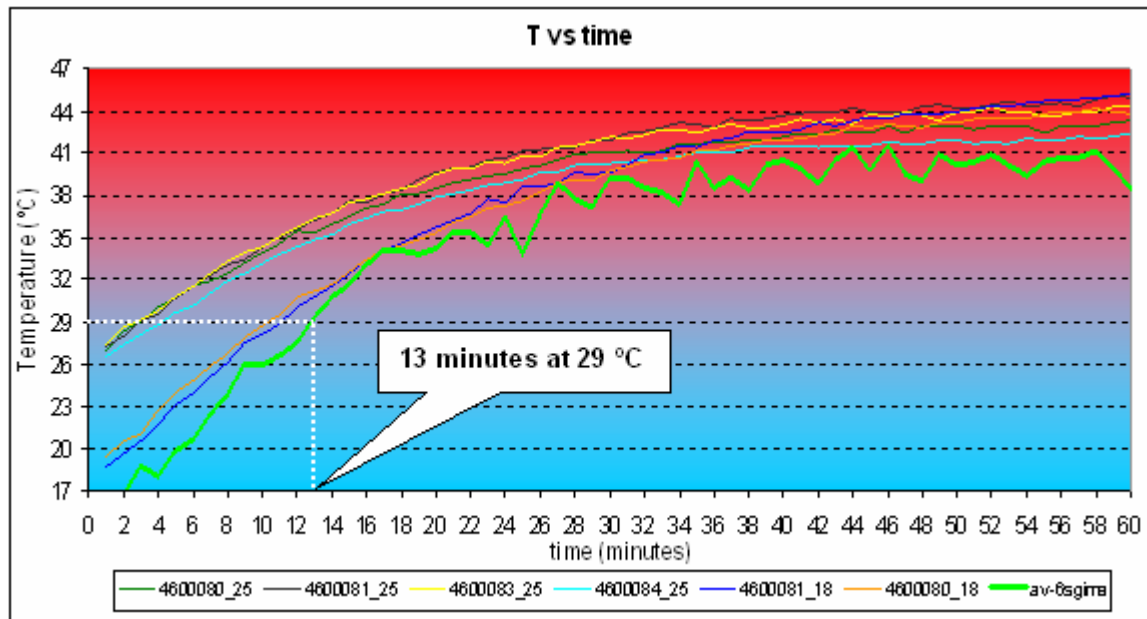


Figure 4.1. Temperature vs. time in warm1

With these 2 conditions we obtained that u' and v' behavior is stable from 29 °C and the temperature is achieved at 13 minutes ageing.

CHAPTER 5. TAKT TIME

In this last chapter we are going to explain the aim of aging time reduction in the line production. We will do it through the takt time, which is the maximum time allowed to produce a product in order to meet demand.

This picture simulates the line production with its positions.

The *assembly process* starts on the right part of the picture at the position “elevador” and continues up to the last buffer. The *JIG process* starts on the AD position and continues up to I5.

We will analyze the *aging time* process, which starts at the first buffer and ends at I3 position. This process is marked in red in *figure 5.1*. and as we can see, it considers 13 positions: 7 buffers, AD, AD_2, LINX1, I1, I2 and I3.

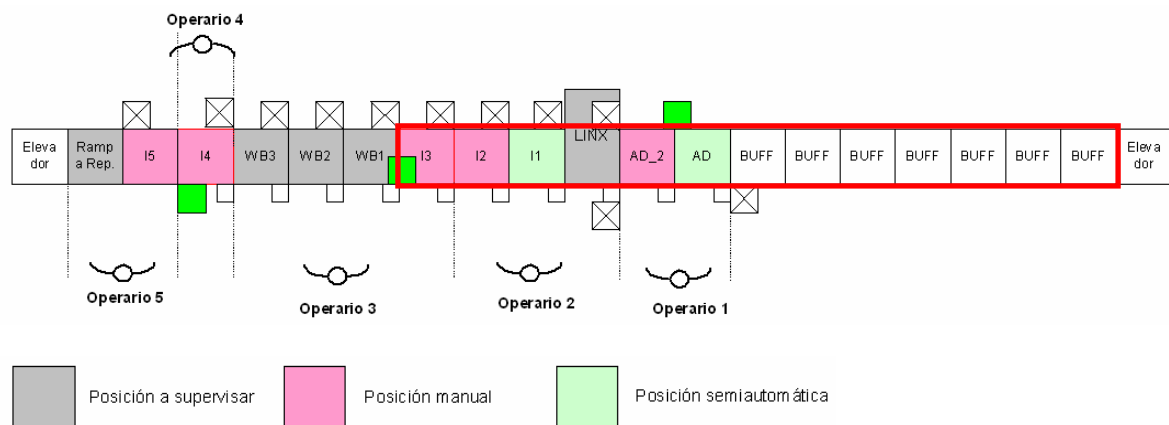


Figure 5.1. Production line positions

In this analysis we will not include the time of ACU (Automatic Connection Unit), pallet transfer nor the connection and disconnection of the televisions.

Table 5.1 Takt time analysis data

Name	Calculation	Value
Production target		300
Number of positions		13
ACU's range	It does not consider a 20% of the time	0,8
Worker shift	7,5 h x 60 x 60	27000 seconds
Maximum Takt time	$27000 \text{ s} / (300 \times 0,8)$	72 seconds / position
Maximum Takt time (30' aging)	$(30 \text{ min} \times 60) / 13 \text{ pos}$	138 seconds / position
Maximum time for the aging time process	$(72 \text{ s} \times 13 \text{ pos}) / 60$	15,6 minutes

In our situation, the maximum takt time for the thirteen positions would be 15,6 minutes (72 seconds per position), which is enough for our process. As we showed in the previous chapter, the minimum ageing time allowed is 13 minutes.

Table 5.2 Takt time analysis data

Position	Time (seconds)
Buffer	58
Buffer	58
Buffer	58
Buffer	58
Buffer	58
Buffer	58
Buffer	58
AD	49
AD_2	48
LINX1	51
I1	50
I2	55
I3	58

And here we have the representation of the processes that take part during aging time:

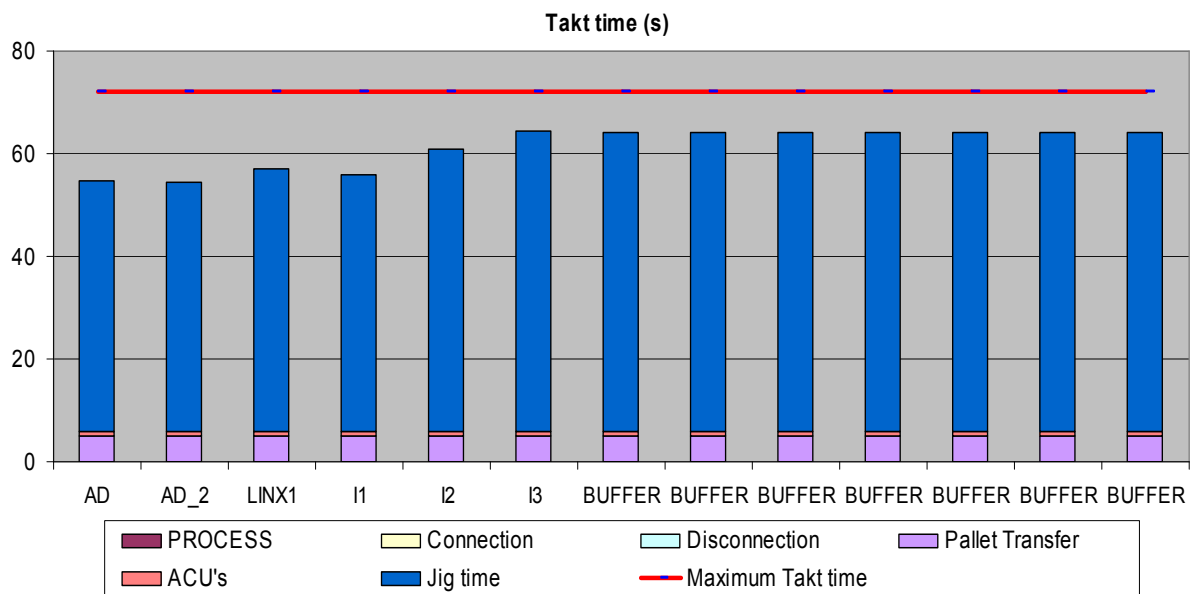


Figure 5.2. Time of every position in aging time process

The buffer takt time is the same time as the position of JIG time that lasts more. In this case is the same time as the I3 position. This is why the problem of bottleneck appears. The more aging time it is, the more buffers will be.

According to the graph, all positions are under the maximum takt time (72 seconds). This takt time is the maximum time a position could last when having 15,6 minutes aging.

On the other hand, if the aging time would be 30 minutes, the takt time would be 138 seconds per position. Almost twice the value of the process at 15,6 minutes aging.

With this process we realize the dimension and the importance of the aging time reduction.

CHAPTER 6. CONCLUSIONS

In this last chapter we are going to show the main conclusions obtained after the development of this project.

The aim of this project was to reduce the aging time of LCD televisions of a production line in SONY BCN TEC to increase the production of televisions. To study the aging reduction of a television, the first step was to study the Gamma behavior and the White Balance behavior.

In accordance with the results obtained in previous chapters, the Gamma behavior is based in an algorithm for every measured luminance point. This is due to the fact that all the sets are following a similar tendency in their behavior. A similar thing happens with the White Balance behavior, which is also based in an algorithm to predict the panel behavior after 30 minutes aging.

These algorithms allow us to “cheat” the system to reach the wanted point at less aging time. The system is 30 minutes aging and the luminance is measured after these 30 minutes. In fact, the television is aging 13 minutes (the value we found optimum) and then the luminance is measured. The values obtained are the ones that should appear at 30 minutes aging.

If the production of televisions increases, the costs and the necessary space for the production will decrease as well as the energy consumption. Finally, we can say that this aging reduction facilitates the quality control and falls into the improvement of other measurement subsystems in production line.

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CHAPTER 8. ANNEX

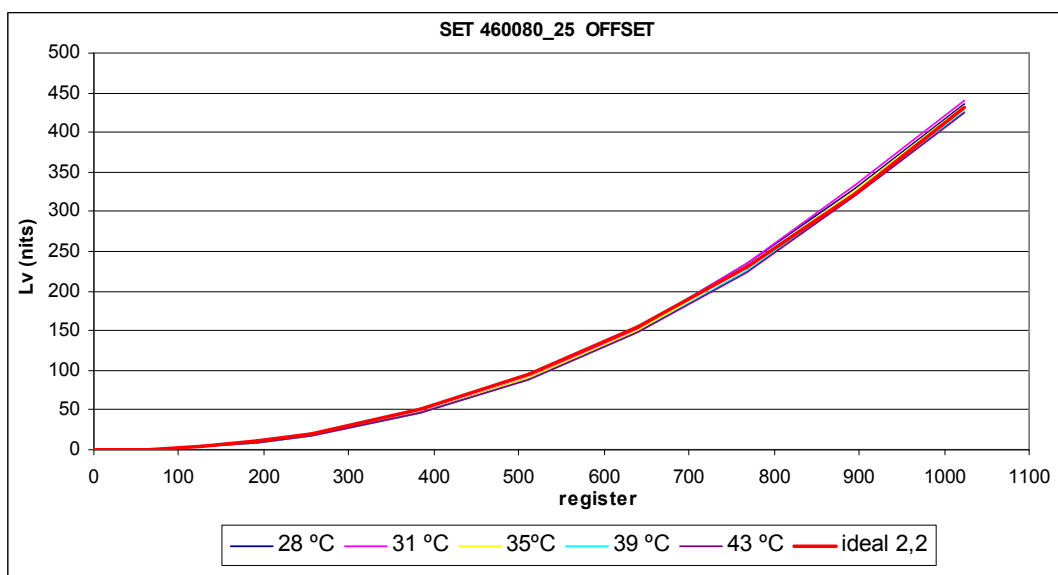
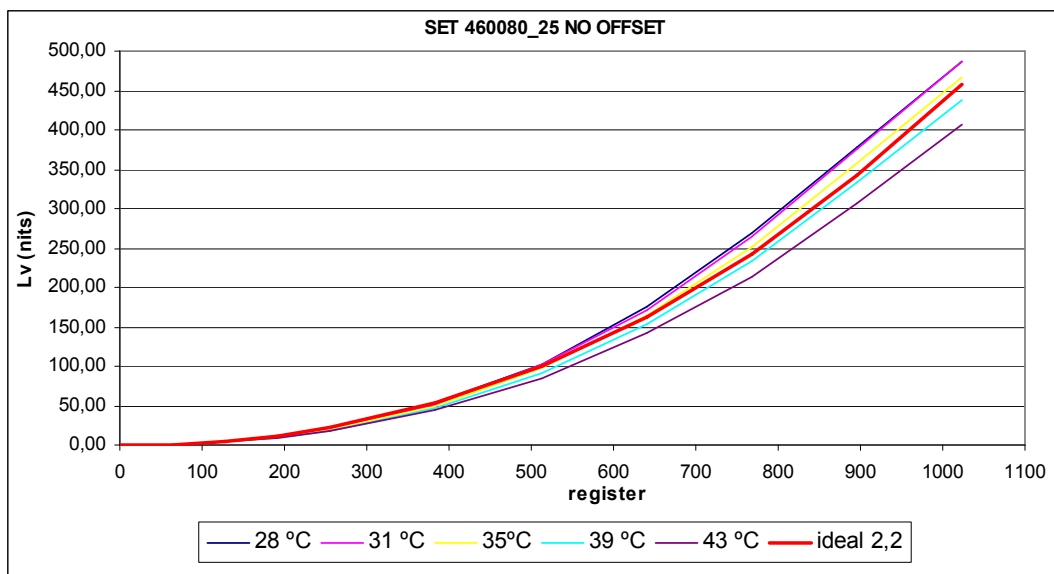
8.1 Gamma Graphs

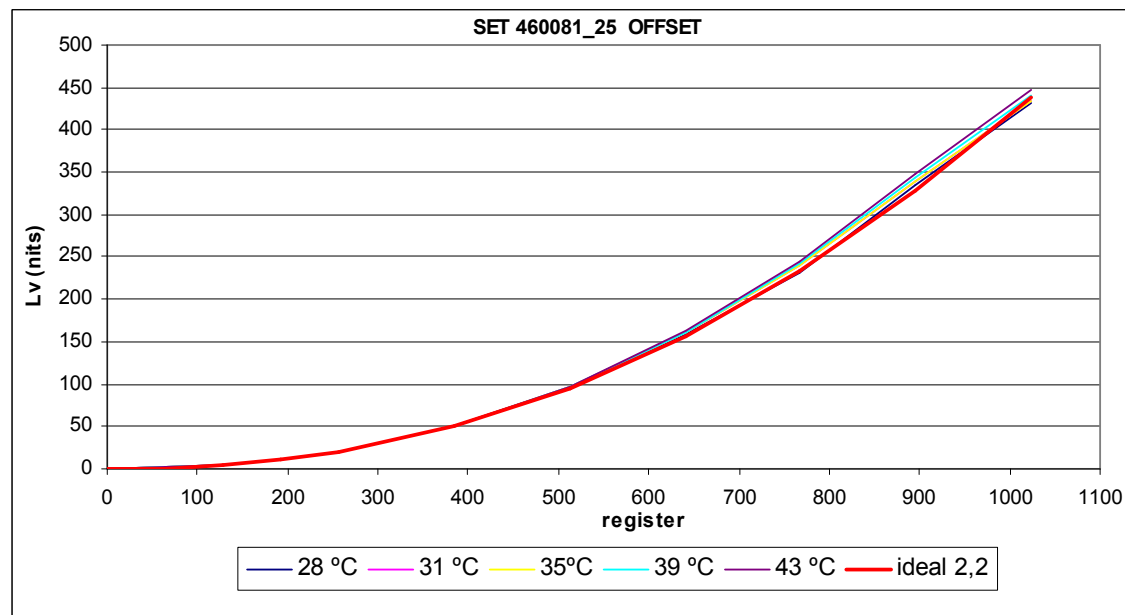
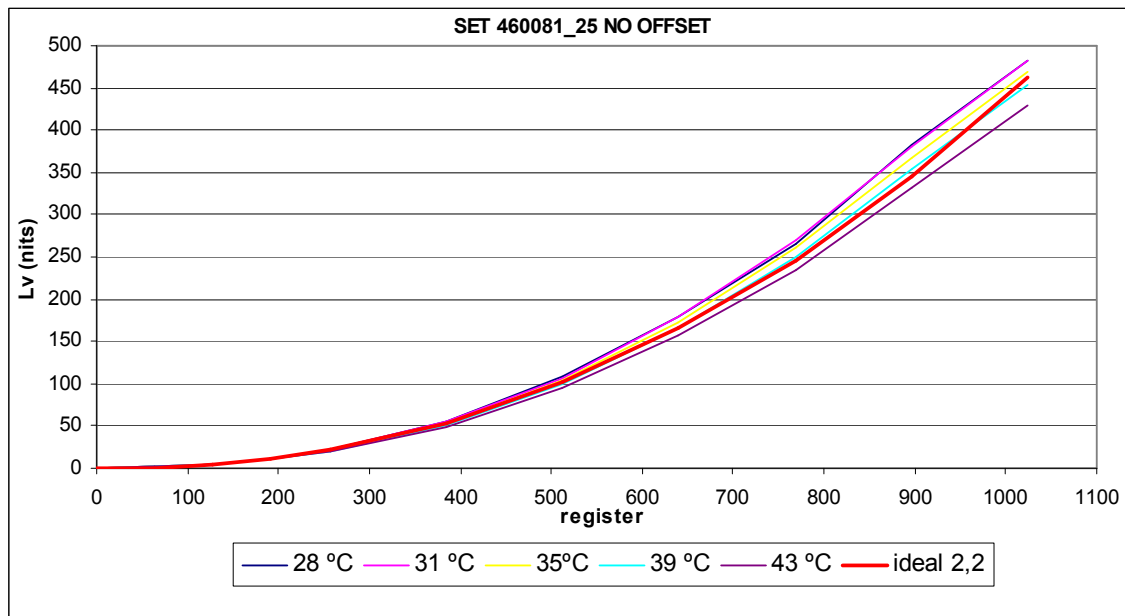
To have an additional comparison between the ideal response and the real response we will have some graphs especially for each set. They represent the response of each television at 28 °C, 31 °C, 35 °C, 39 °C and 43 °C. We can see the evolution of the luminance as the register increases the level for the response with offset and without it.

The main comment for these graphs is that when there is no offset, there is dispersion around the ideal exponential curve. However, when the offset is applied, all the curves are grouped around the ideal curve.

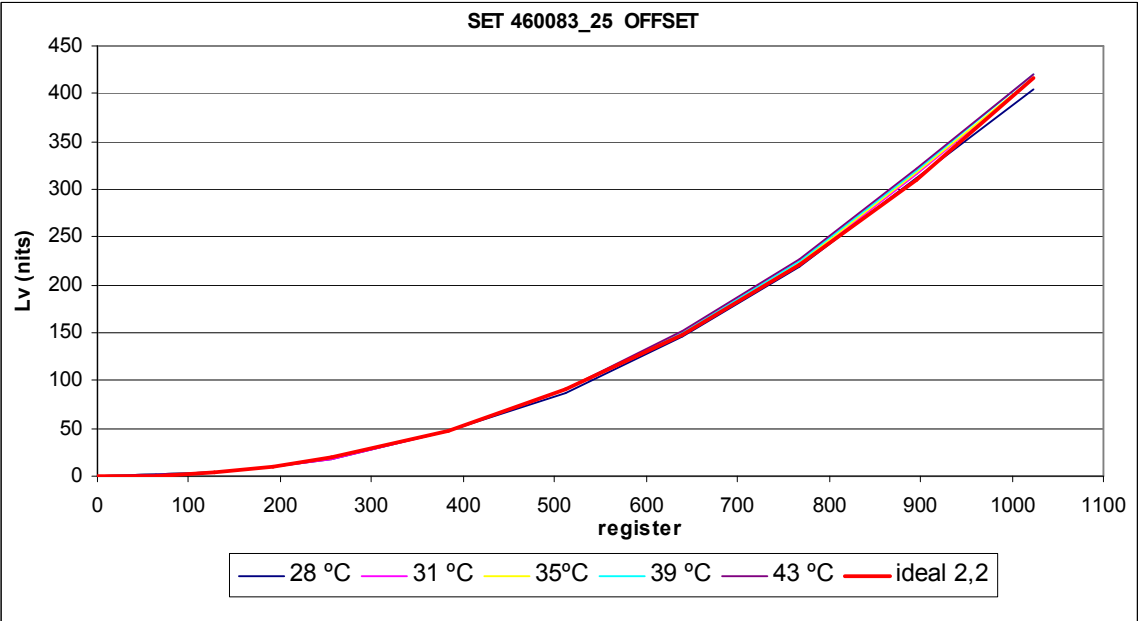
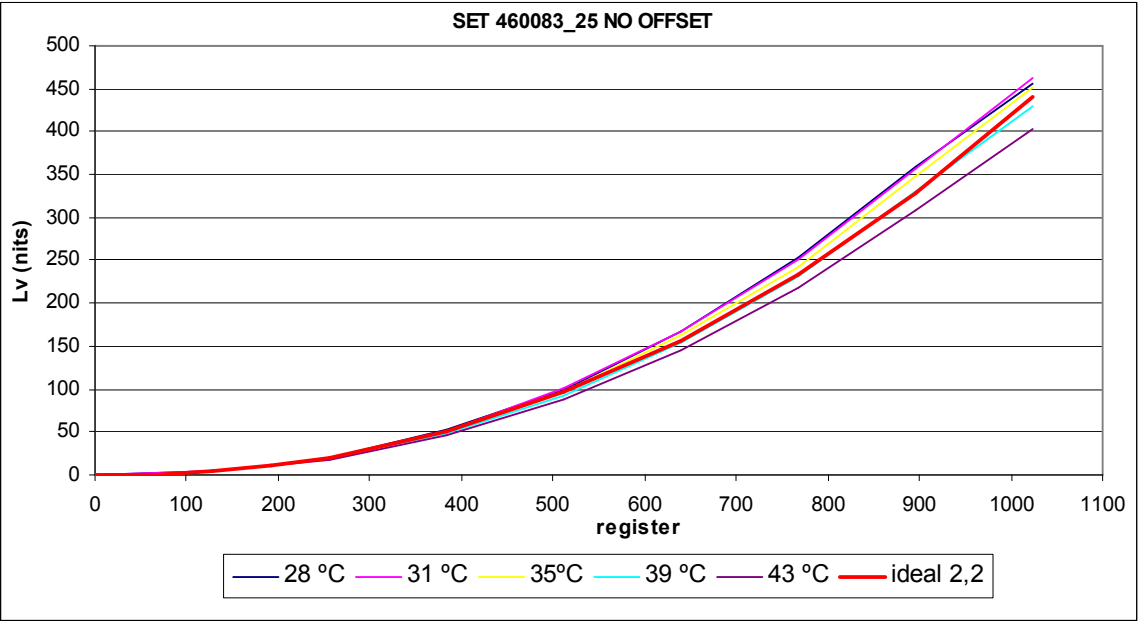
These graphs are just to reaffirm the results.

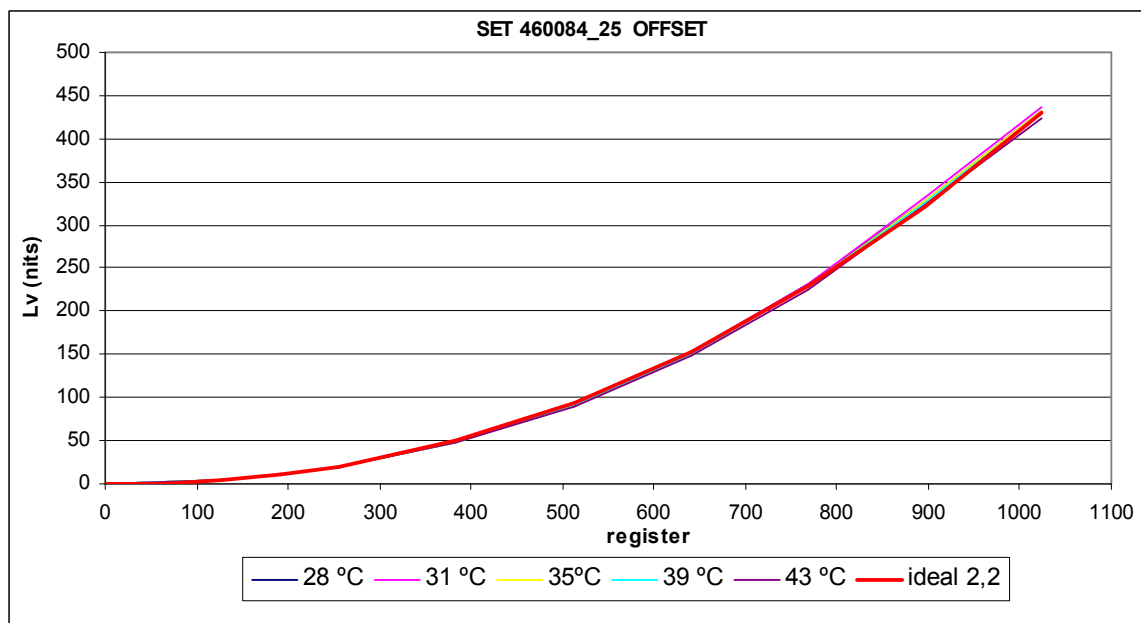
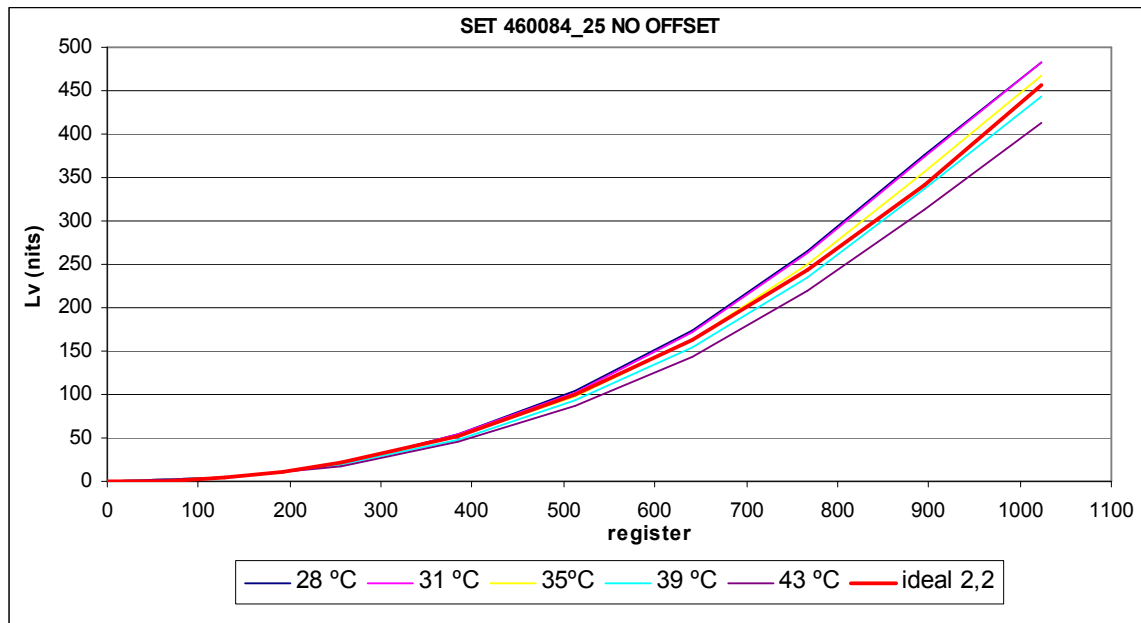
Set 460080 at 25 °C



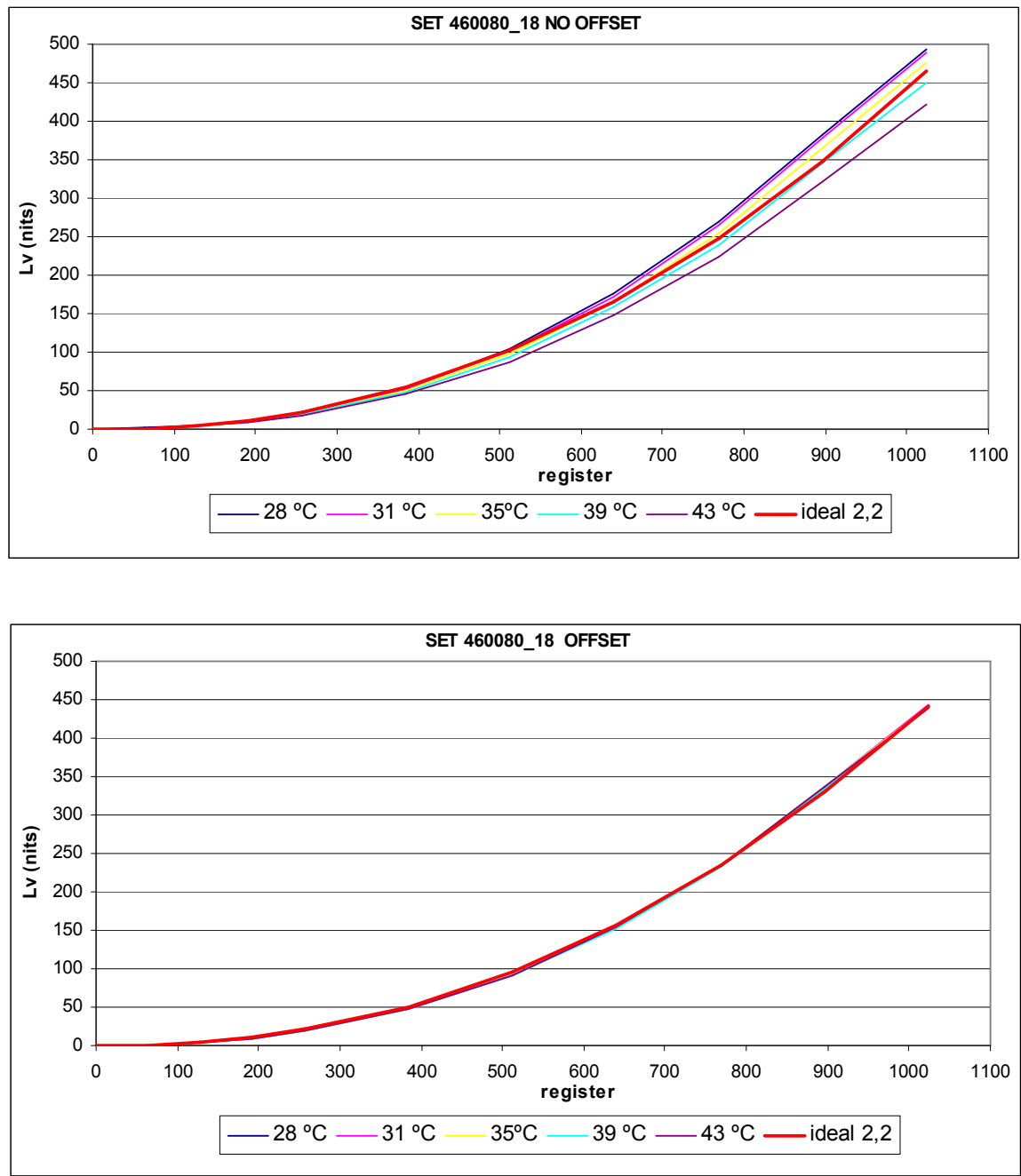
Set 460081 at 25 °C

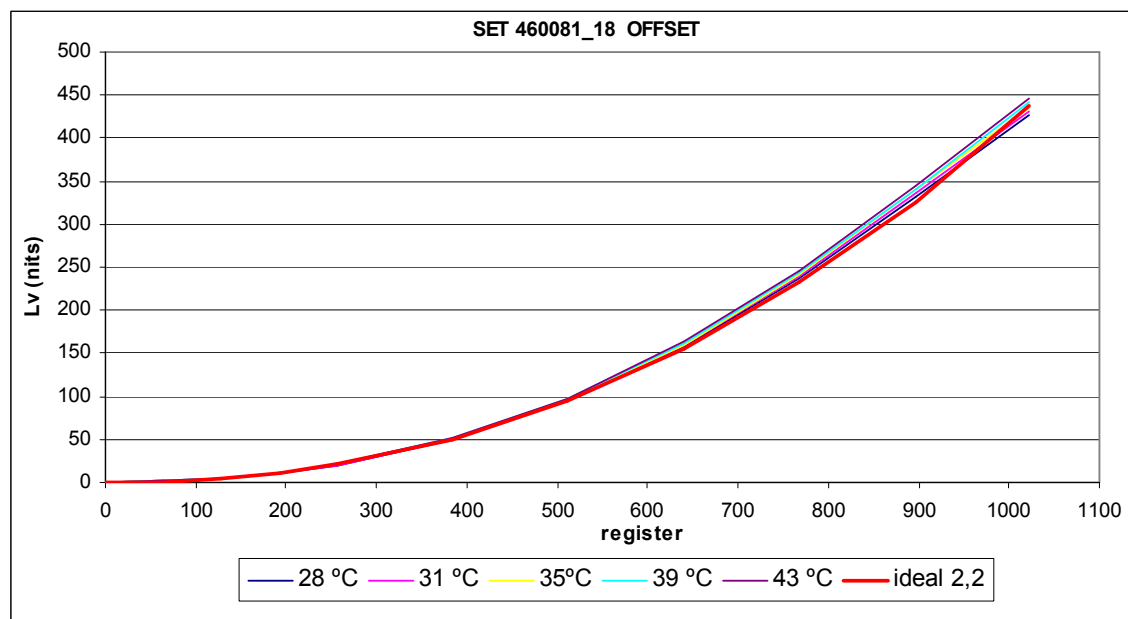
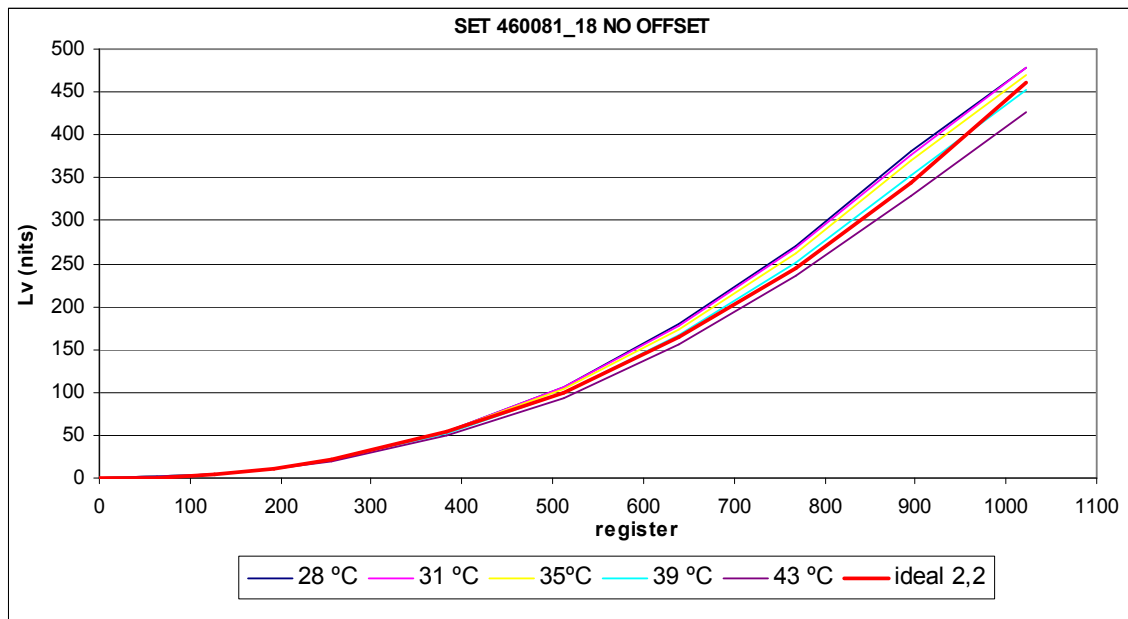
Set 460083 at 25 °C



Set 460084 at 25 °C

Set 460080 at 18 °C



Set 460081 at 18 °C

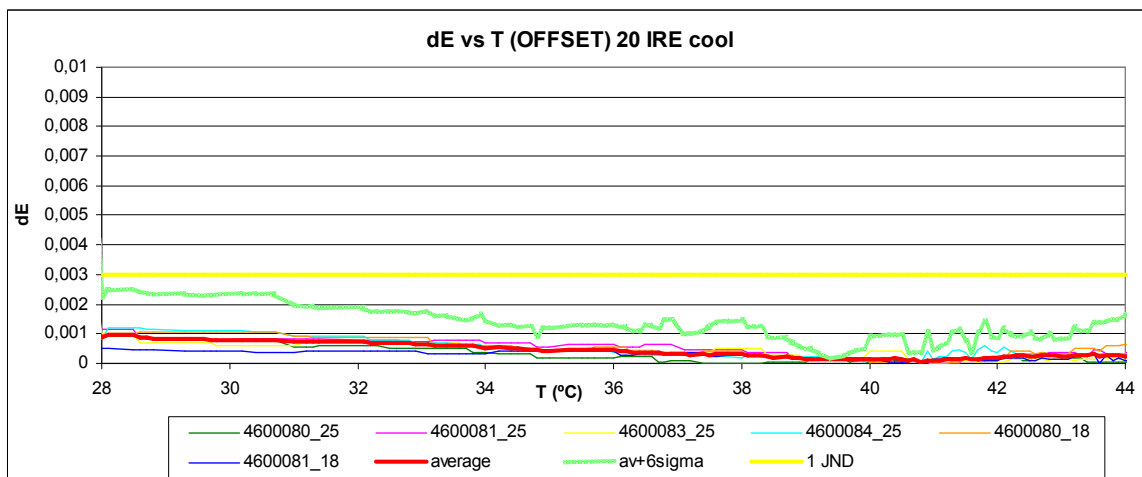
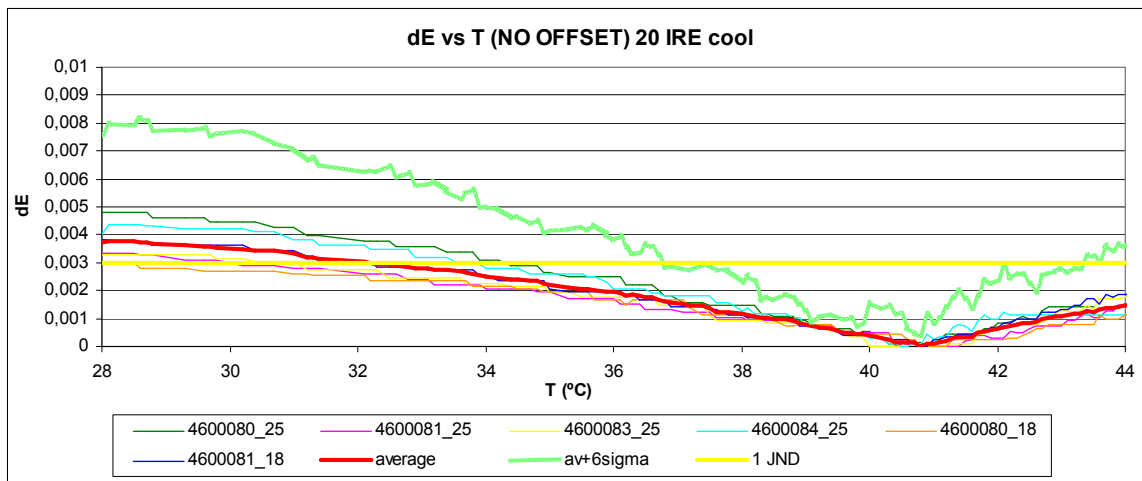
8.2 White Balance graphs - ΔE with and without offset

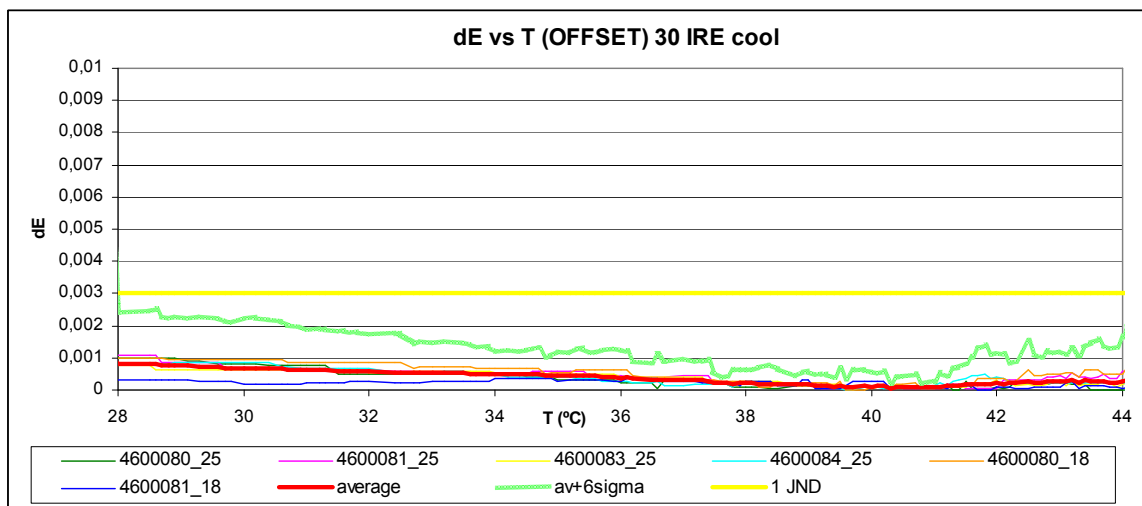
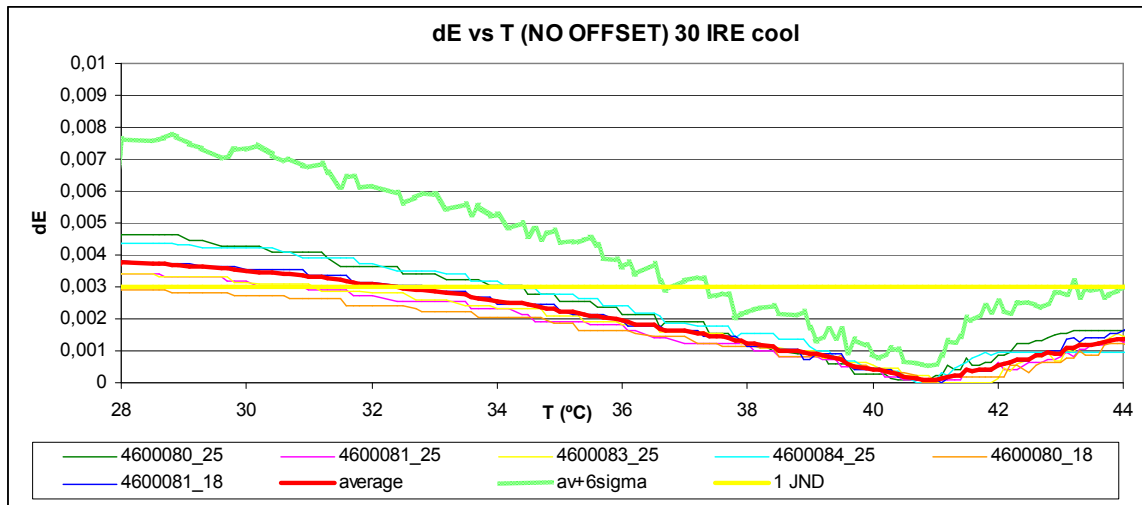
Now that we have both ΔE we can represent the graphs. We will represent the 20, 30, 50, 70 and 90 IRE graphs for the cool register, and also the graph of 20 IRE for the neutral, warm1 and warm2 registers.

These graphs will allow us to know how many minutes can we reduced of ageing time by choosing the worst case of the register and of the signal level.

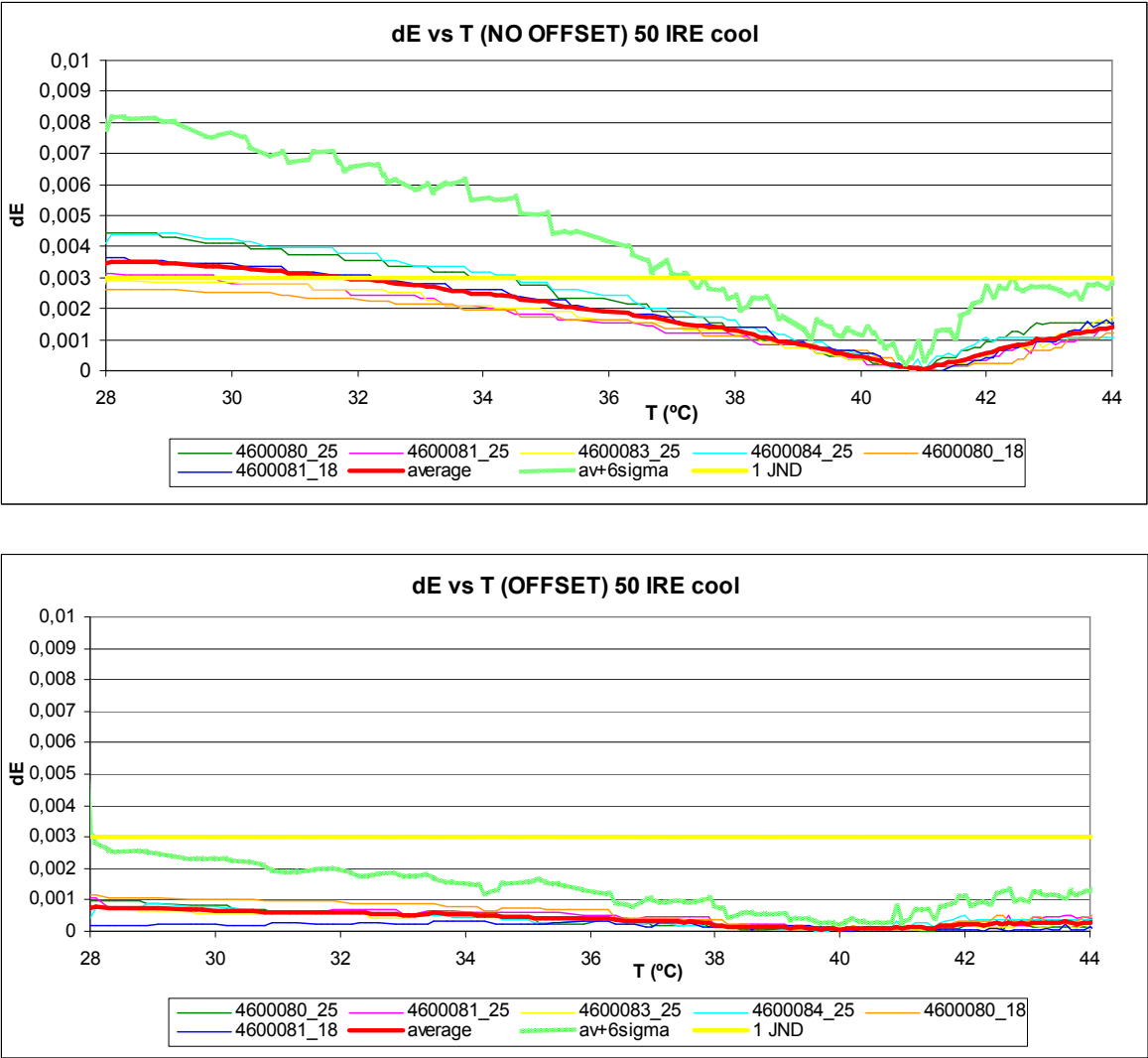
(*) In the graphs ΔE is called dE .

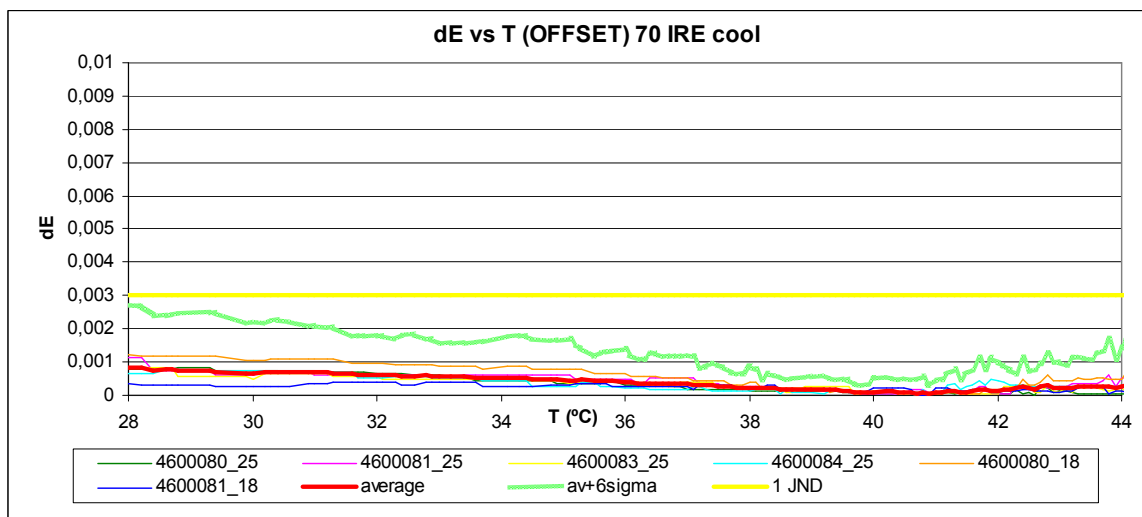
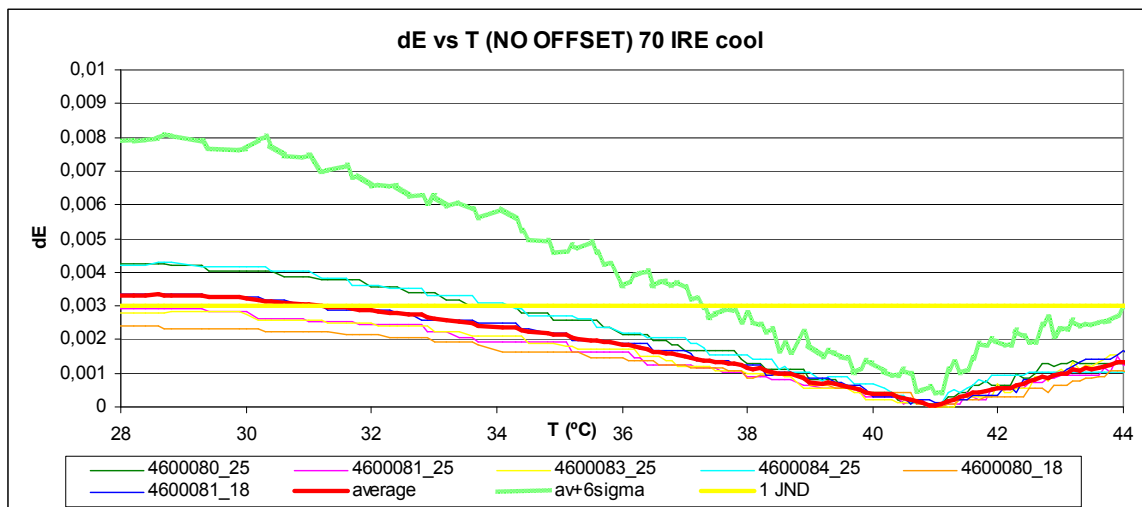
20 IRE cool



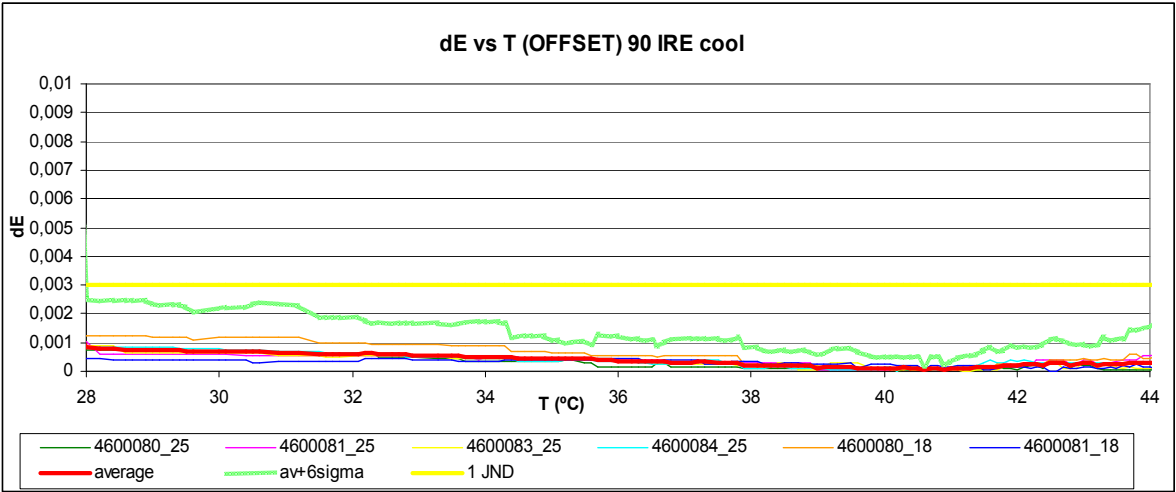
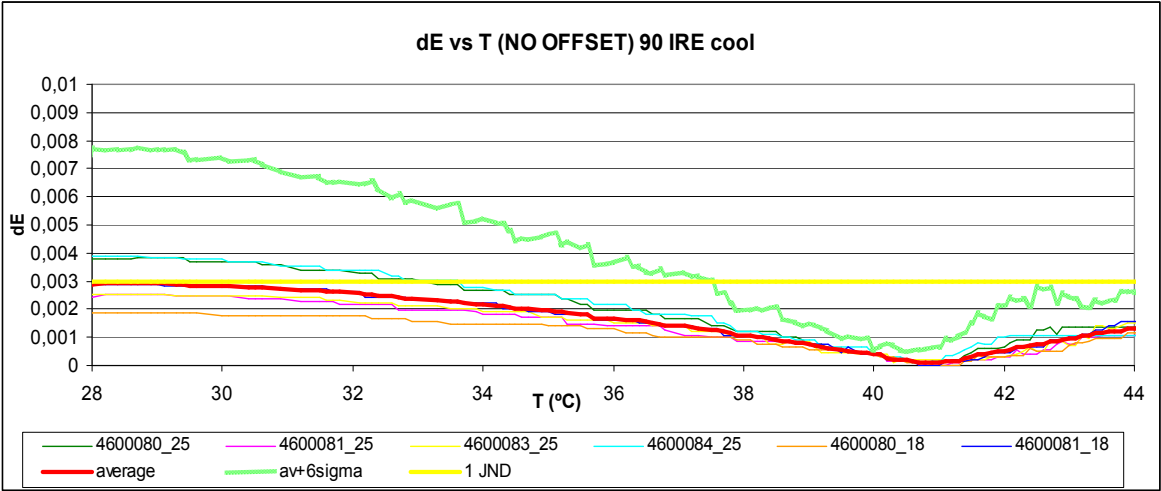
30 IRE cool

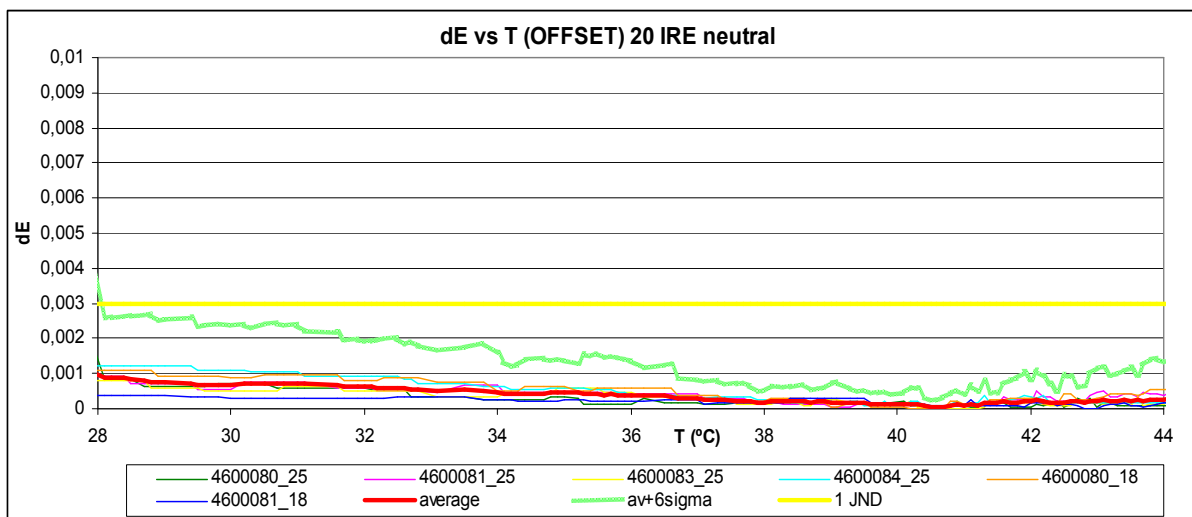
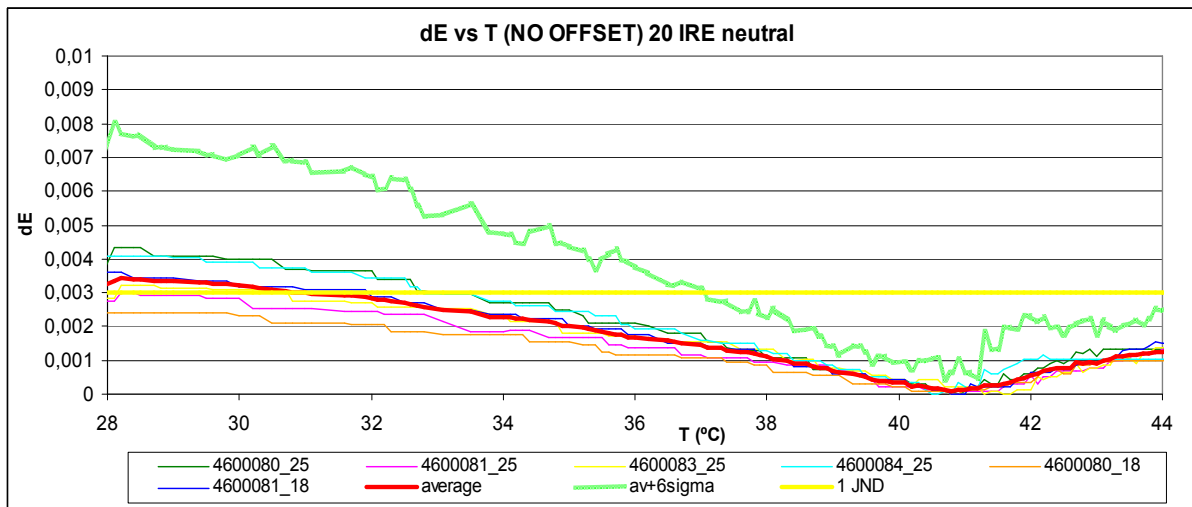
50 IRE cool

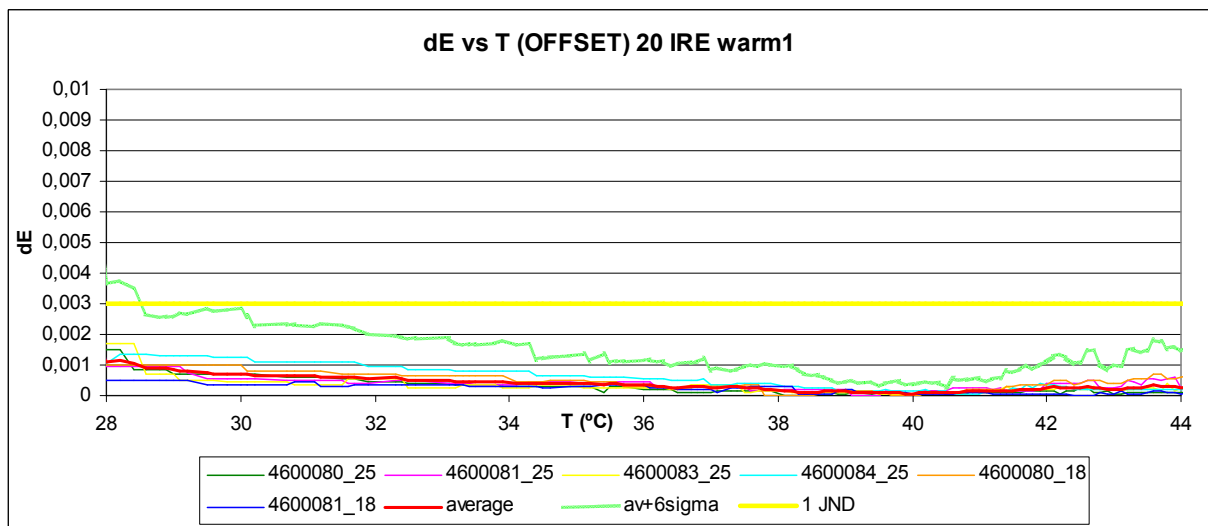
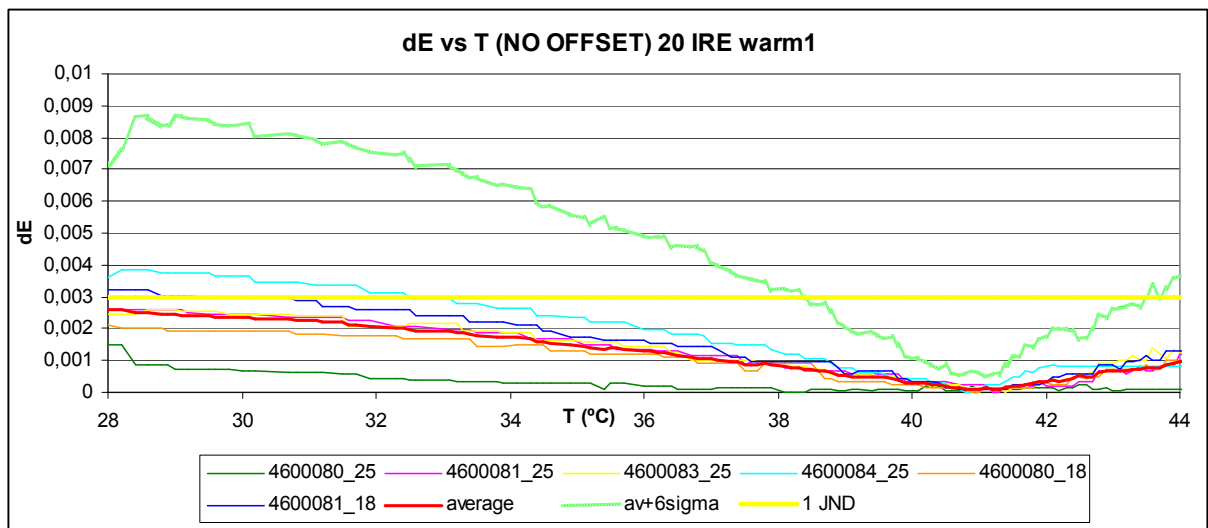


70 IRE cool

90 IRE cool



20 IRE neutral

20 IRE warm1

20 IRE warm2